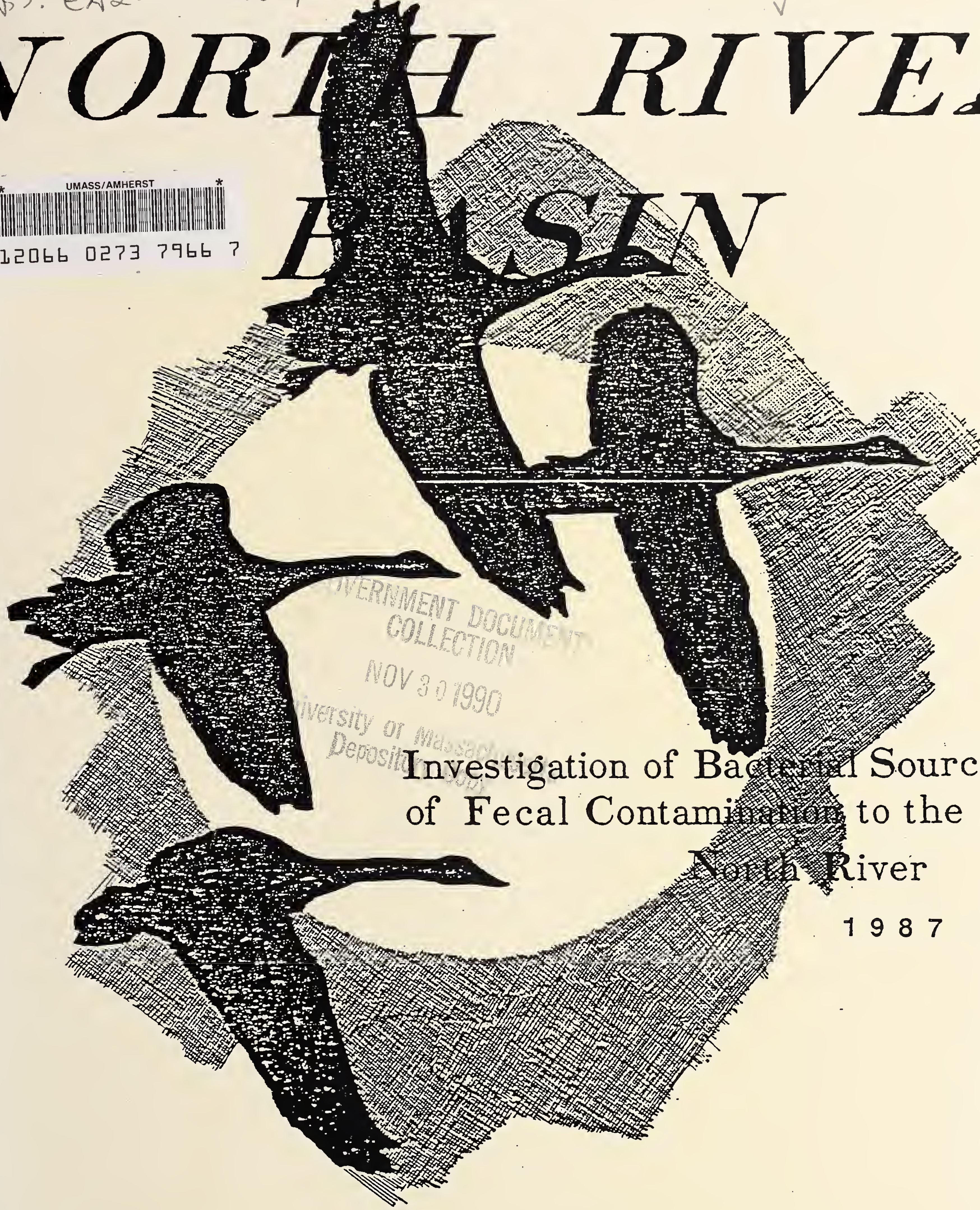
NORTH RIVER BASIN



Investigation of Bacterial Sources of Fecal Contamination to the North River

1987

Department of Environmental Protection
DIVISION of WATER POLLUTION CONTROL
Arleen O'Donnell, Acting Director

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INVESTIGATION OF BACTERIAL SOURCES OF

FECAL CONTAMINATION TO THE NORTH RIVER

1987

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APRIL 1990

TITLE: Investigation of Bacterial Sources of Fecal Contamination to the North River - 1987

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FOREWORD

The Massachusetts Division of Water Pollution Control was established by the Massachusetts Clean Water Act, Chapter 21 of the General Laws as amended by Chapter 685 of the Acts of 1966. Included in the duties and responsibilities of the Division is the periodic examination of the water quality of various coastal waters, rivers, streams, ponds, and wetlands of the Commonwealth, as stated in section 27, paragraph 5 of the Acts. This section further directs the Division to publish the results of such examinations together with the standard of water quality established for the various waters. One of the responsibilities of the Technical Services Branch of the Division of Water Pollution Control is the execution of this directive. This report is published under the Authority of the Acts and is among a continuing series of reports issued by the Division presenting water quality data and analyses, water quality management plans, baseline and intensive limnological studies and various special studies.

EXECUTIVE SUMMARY

During the summer of 1987, the Massachusetts Division of Water Pollution Control - Technical Services Branch, surveyed part of the North River located in the towns of Scituate, Norwell and Marshfield, from Curtis Crossing down to and including, the Herring River. Bacteria and nutrients were sampled eight times over the period June to September.

Source differentiation of the fecal streptococci bacteria was done in an attempt to identify types of nonpoint sources of fecal contamination that are predominant in the watershed. Three sampling areas were delineated:

Area I	Curtis Crossing to "Dwelleys Creek"
Area II	"Dwelleys Creek" to Mary's Landing
Area III	Mary's Landing to the mouth of the river including the Herring River.

Septic tank leachate may contribute to bacterial counts in the tributaries, particularly in the vicinity of Howard Pond and Mounce Pond. Because of sparse housing development along the river, leachate is not as much of a problem along the mainstem of the North River.

Storm drains carrying dry and wet weather flows to the North River are an important source of bacteria and nutrients. Several drains were noted flowing even during dry weather and were found to carry fecally contaminated water. Those with problems include:

Shrine Road, Norwell - discharges to "Dwelleys Creek,"

Riverside Circle, Marshfield - discharges to the North River,

Drain adjacent to Mary's Landing, Marshfield - discharges to the North River,

Driftway, Scituate - discharges to the Herring River.

The tributaries to the North River are often significant sources of fecal and nutrient contamination. In particular, "Dwelleys Creek," Stony Brook and the outlet tributaries from Howard Pond and Mounce Pond are contaminated. These upstream sources contribute to the seasonal closure of shellfishing areas in the North River below Route 3A Bridge and to permanent closure above Route 3A.

The Herring River is a major contributor of fecal streptococci from warmblooded animals. This area was the most complex in terms of land use and not all sources of fecal contamination are yet described. The Scituate Wastewater Treatment Plant discharge is one of the contributors of fecal coliform bacteria. However, samples collected at James Landing (formerly Simm's Boatyard) were inconclusive. Very high fecal coliform counts here indicate that a major dumping of fecal waste occurred somewhere along the Herring River. Further monitoring and study of the tidal patterns are needed in this area. In any case, installation and proper use of a pump-out facility by James Landing Marina could improve water quality in this area.

There is some indication that both nutrients and fecal coliform bacteria may be contributed to the North River via intertidal waters over marshlands. The tidally influenced marshland at "Dwelleys Creek" appeared to be a source of nitrogen measured as total Kjeldahl-nitrogen and fecal coliform bacteria. But, much further investigation is required to provide a definitive answer.

Intermittent discharges caused by septage haulers improperly disposing of their holding tanks is extremely difficult to monitor. However, citizens have reported seeing sewage slicks on the river, and sampling in the Herring River also indicated that some type of dumping occurred. It is recommended that the area towns devise a plan to track both what the haulers are doing with their septage waste, as well as where it is being generated.

ACKNOWLEGMENTS

The Division of Water Pollution Control's Technical Services Branch would like to thank those groups and individuals whose efforts contributed to the accomplishment of this study. In particular we would like to thank:

Richard Dorfman, Environmental Engineer, who was the Chief Field Investigator for this study.

Rosario Grasso, who was Chief of the Bacteriology Lab, Lawrence Experiment Station at the time of this study and is now retired and his assistant during the summer of 1987, James R. Brown. These people were responsible for all the bacterial analysis;

Jim Sullivan and the staff at Lawrence Experiment Station who performed the chemical analyses;

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INTRODUCTION

Closure of shellfish areas in the North River estuary in southeastern Massachusetts has reduced the use of this scenic waterway for area residents and other visitors. In the towns of Scituate and Marshfield 104.5 acres are permanently closed for shellfishing and 208.6 acres are seasonally closed (personal communication with Massachusetts Division of Marine Fisheries). Seasonal closure extends from May to October. The seasonally closed area lies east of the Route 3A Bridge, Scituate and west of a line drawn 400 meters from the mouth of the North River (Figure 1). The permanently closed area extends west of the Route 3A Bridge up to the Curtis Crossing Dam. Areas are closed for shellfishing when a geometric mean of five samples exceeds 14 fecal coliform MPN/100 ml with no more than 10 percent exceeding 43 MPN/100 ml. Elimination of the sources of bacteria would eventually lead to the reopening of the shellfish beds and reduce the risk of losing the use of the river for other recreational activities such as swimming. The North River is classified SA (MA Div. of Water Pollution Control, 1985) from the mouth of the river to mile 10.7 (Third Herring Brook, Hanover) and SB from there to Curtis Crossing, Hanover (mile point 12.9) (see Table 1). Both SA and SB classifications allow for primary contact recreation such as swimming, but only SA allows the harvesting of shellfish without depuration. Currently, there are bacterial sources contributing to the closure of the shellfish beds and the inability of the river to meet SA, SB standards. However, there are major difficulties in locating where the bacteria emanate. Typically the sources are really diffuse or sporadic (seasonal, diurnal, etc). Many people speculate on what is causing the contamination, but typically the sources are not easily identified or verified. When a discharge occurs, factors such as volume of material discharged and circulation mixing patterns in an area can affect the density of bacteria present at a sample site.

During the summer of 1987, the Massachusetts Division of Water Pollution Control - Technical Services Branch, attempted to determine the types of sources that are causing elevated bacterial counts in the North River. Sampling was performed from Curtis Crossing down to, and including, the Herring River. Bacteria and nutrient samples were collected during most weeks over the period of June to September 1987. The objective of this study was to examine if nonpoint sources of fecal contamination to the North River and the estuary were causing elevated bacterial counts and contributing to the closure of the shellfish beds. Nonpoint source pollution as defined by the MA Div. of Water Pollution Control's - Nonpoint Source Program "is caused by diffuse sources that are not regulated as point sources and normally is associated with agricultural, silvicultural (forestry) and urban runoff, runoff from construction activities, etc." Also, an opportunity existed to evaluate the usefulness of identifying the types of nonpoint sources of fecal contamination that were predominant in the watershed using a method of source differentiation of the fecal streptococci bacteria.

Why look for nonpoint sources of fecal contamination? In the area of the North River included for study there is only one point source of fecal contamination, the Scituate Wastewater Treatment Plant. Although the Scituate WWTP does discharge to a tributary of the North River, its impact alone can not account for the elevated bacterial levels that extend up to Curtis Crossing approximately 13 miles from the mouth of the North River. Many nonpoint sources of fecal contamination contribute to the closure of the North River for

FIG 1 *NORTH RIVER BASIN*

AREAS I, II & III

TABLE 1

MASSACHUSETTS SURFACE WATER QUALITY STANDARDS FOR SA AND SB WATERS

Class SA Waters:

<u>PARAMETER</u>	<u>CRITERIA</u>
Dissolved Oxygen	Shall be a minimum of 85 percent of saturation at water temperature above 77°F (25°C) and shall be a minimum of 6.0 mg/l at water temperatures of 77°F (25°C) and below.
Temperature Increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
pH	Shall be in the range of 6.5-8.5 standard units and not more than 0.2 units outside of the naturally occurring range.
Total Coliform Bacteria	Shall not exceed a median value of 70 MPN per 100 ml and not more than 10 percent of the samples shall exceed 230 MPN per 100 ml in any monthly sampling period.

Class SB Waters:

<u>PARAMETER</u>	<u>CRITERIA</u>
Dissolved Oxygen	Shall be a minimum of 85 percent of saturation at water temperatures above 77°F (25°C) and shall be a minimum of 6.0 mg/l at water temperatures of 77°F (25°C) and below.
Temperature Increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
pH	Shall be in the range of 6.5-8.5 and not more than 0.2 units outside of the naturally occurring range.
Total Coliform Bacteria	Shall not exceed a median value of 700 MPN per 100 ml and not more than 20 percent of the samples shall exceed 1000 MPN per 100 ml during any monthly sampling period, except as in 314 CMR 4.02(1).

shellfishing. These include: marinas, bird populations, parking lots and other paved areas, septic system leaching fields, and storm drainage systems. In non-residential or non-urban areas, agricultural runoff from pastures and feed lots may prove important. Along the North River both fresh and salt water marshes are common from the area of Curtis Crossing down to the Herring River where the salt water marsh combines with the many uses of the Scituate downtown area described above. The many small mammals, insects and birds that inhabit these marsh areas can contribute streptococci bacteria and fecal coliform bacteria which then can make their way to the North River via tidal water or runoff. The bacteria that break down the vegetation in these marshes can also appear in the North River.

All of these different land uses and land types have the potential to contribute varying amounts and types of nutrients and bacteria to the river. It would be useful for management purposes to be able to learn what types of sources are major fecal contributors to the river. One method used to do this is to differentiate the fecal streptococci bacteria into species or groups of species. The presence of fecal streptococci bacteria as well as the fecal coliform bacteria is an indication of fecal contamination. The fecal streptococci are defined as those species of streptococci bacteria that are recovered from feces in significant quantities. The fecal streptococci bacteria is composed of the following species:

- S. faecalis
- S. faecium
- S. zymogenes
- S. bovis
- S. equinus
- S. avium
- S. mitis

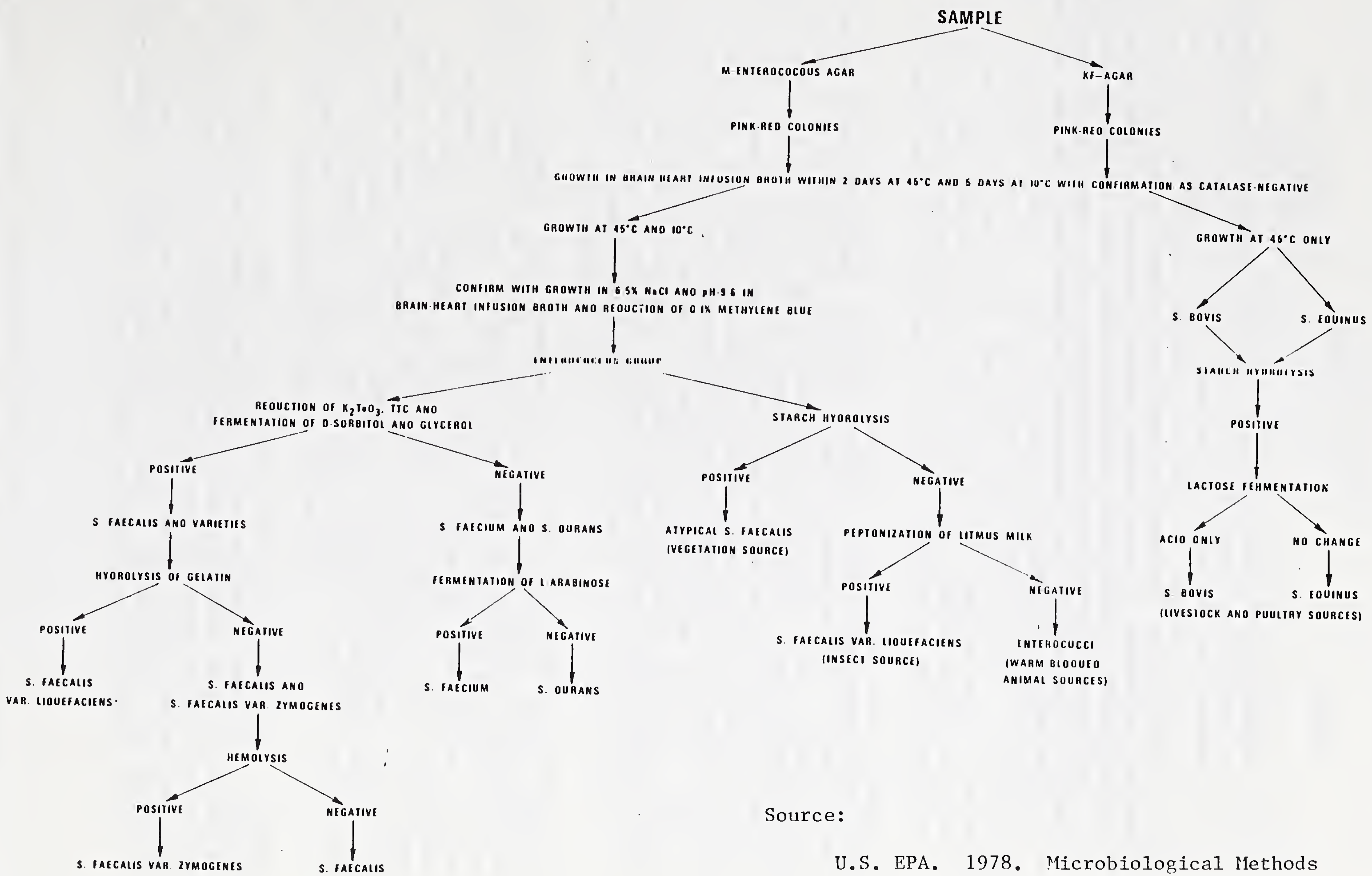
By using a method of several biochemical tests compiled by the U.S. EPA, personnel from Technical Services Branch of the Division of Water Pollution Control were able to distinguish either the species present in a sample or a group of species, both of which would indicate sources (see Figure 2). Species differentiation was done on two occasions while source differentiation, from groups of species, was done six times. The sources that could be distinguished were:

- warmblooded animals
- livestock (cows, horses)
- insects
- vegetation
- birds

The species differentiated could also be categorized in the above sources using the following generalized scheme:

warmblooded	S. faecalis S. faecium S. faecalis var. zymogenes
livestock	S. equinus S. bovis

FIGURE 2 SCHEMATIC OUTLINE FOR IDENTIFICATION OF FECAL STREPTOCOCCI



Source:

U.S. EPA. 1978. Microbiological Methods for Monitoring the Environment Water and Wastes.

insects	S. faecalis var. liquefaciens
vegetation	atypical fecal streptococci
birds	S. avium

At the North River the fecal streptococci sources were typically warmblooded animals, although, in some areas sampled, insects and vegetation also were common sources. The species isolated indicate that humans are a major source of fecal contamination to the North River. This conclusion is believed to be true for both areas of the river near "Dwelleys Creek", as well as, down to and including the Herring River.

SAMPLING DESIGN

Samples were collected by personnel from the Division of Water Pollution Control at the North River typically once per week from June to September 1987. Sampling was done by boat on an outgoing tide, as this was believed to be a worse-case situation. Large areas of shoreline are wetted two times per day and as the tide recedes bacteria, as well as dissolved and particulate contaminants, can be contributed to the tidal waters. Flooding of leaching fields may occur in houses constructed with their septic systems located within 50 feet of the shore. This may cause surface break outs of wastewater or the possibility exists that nutrients might travel through the wetted soils. Because the sampling area extended over so great a distance the river was divided into three reaches. Area I extended from Curtis Crossing Dam down to "Dwelleys Creek." Area II went from "Dwelleys Creek" to Mary's Landing and Area III from Mary's Landing to the mouth of the North River, including the Herring River (see Figures 3,4,5, Tables 2,3,4,5). Samples were collected by hand from a 14 foot Boston Whaler. An effort was made to sample as close to shore as possible and to go upstream into the tributaries as far as possible.

All work was preceded by site reconnaissance to locate areas where changes in the riparian land environment occurred, such as, urban development with large paved areas, salt marsh, salt marsh to upland vegetation, etc. Stations were located above and below these alterations in riparian land types whenever possible since these could affect runoff contributions. Areas identified in the BSC Group (1987) report as problem areas of bacterial contamination were used as the basis for choosing areas for further study. The primary objective of this work was to try to differentiate the various types of sources of fecal contamination to the North River. A sampling priority was to locate areas of high bacterial densities and major riparian environmental changes. Sampling was done above and below marinas, housing areas, and as stated, where changes from salt marsh to woodland areas, etc., occurred. Also, storm drains that flow continually were sampled.

The bacterial indicator, fecal streptococci bacteria, was used to differentiate the types of sources of fecal contamination. The types which could be differentiated are: birds, vegetation, warmblooded animals, livestock, and insects. Because of limitations in holding times for the bacterial samples only 12 samples were typically collected for source differentiation. On two dates, when an extra field crew was used to sample in the tributaries, additional samples were analyzed. Besides bacteria, samples were also analyzed for ammonia-nitrogen, nitrate-nitrogen, Kjeldahl-nitrogen, and total phosphorus. Temperature, pH, hardness, chloride, suspended solids and dissolved oxygen were also analyzed. Chemical and bacterial samples were brought to the Lawrence Experiment Station for analysis.

Discharge patterns from a point source such as the Scituate WWTP are different from those of nonpoint sources which are more weather dependent. Nonpoint sources discharge on an intermittent basis and typically have to be sampled during rain events. Rainfall was limited during the summer of 1987 so what was sampled was that which was carried by tidal water, storm drains that flow during dry weather, seepage from septic tanks. In addition, dry deposition from the atmosphere as well as wind erosion can contribute nutrients, while

TABLE 2

LOCATION OF SAMPLING STATIONS

NORTH RIVER

AREA I

Station Number	Location Description	Mile Point	Kilometer Point
NR15	Near Curtis Crossing, south side of the river downstream of the Elm St. Bridge, Hanover	12.9	20.8
NR14	Midstream of the North River, downstream of Washington St. Bridge, Hanover	11.3	18.2
THB01	Midstream of Third Herring Brook, approximately 40 yards north of the first bend in the brook, Hanover	11.0,0.19	17.7,0.3
NR13	North side of the North River, downstream of Third Herring Brook and just downstream of house at Fox Hill Lane, Norwell	10.5	16.9
HP01	Midstream of unnamed brook, outlet of Howard Pond, Norwell, approximately 20 yards south of the confluence with North River at the first bend in the brook, Pembroke	10.0,0.19	16.1,0.3
NR12	East side of the North River, downstream of the Schoosett St., boat ramp, Pembroke	9.8	15.8
NR11	North side of the North River, approximately 30 yards southeast of Till Rock at Till Rock Lane, Norwell	9.1	14.6
NR10	Midstream of the North River, approximately 10 yards downstream of the Route 3 Bridge, Marshfield	8.1	13.0
NR09	East side of the North River, second to the northern most outlet of Mounce Pond, Marshfield	7.6	12.2

FIG 3 *NORTH RIVER BASIN* AREA I sampling stations

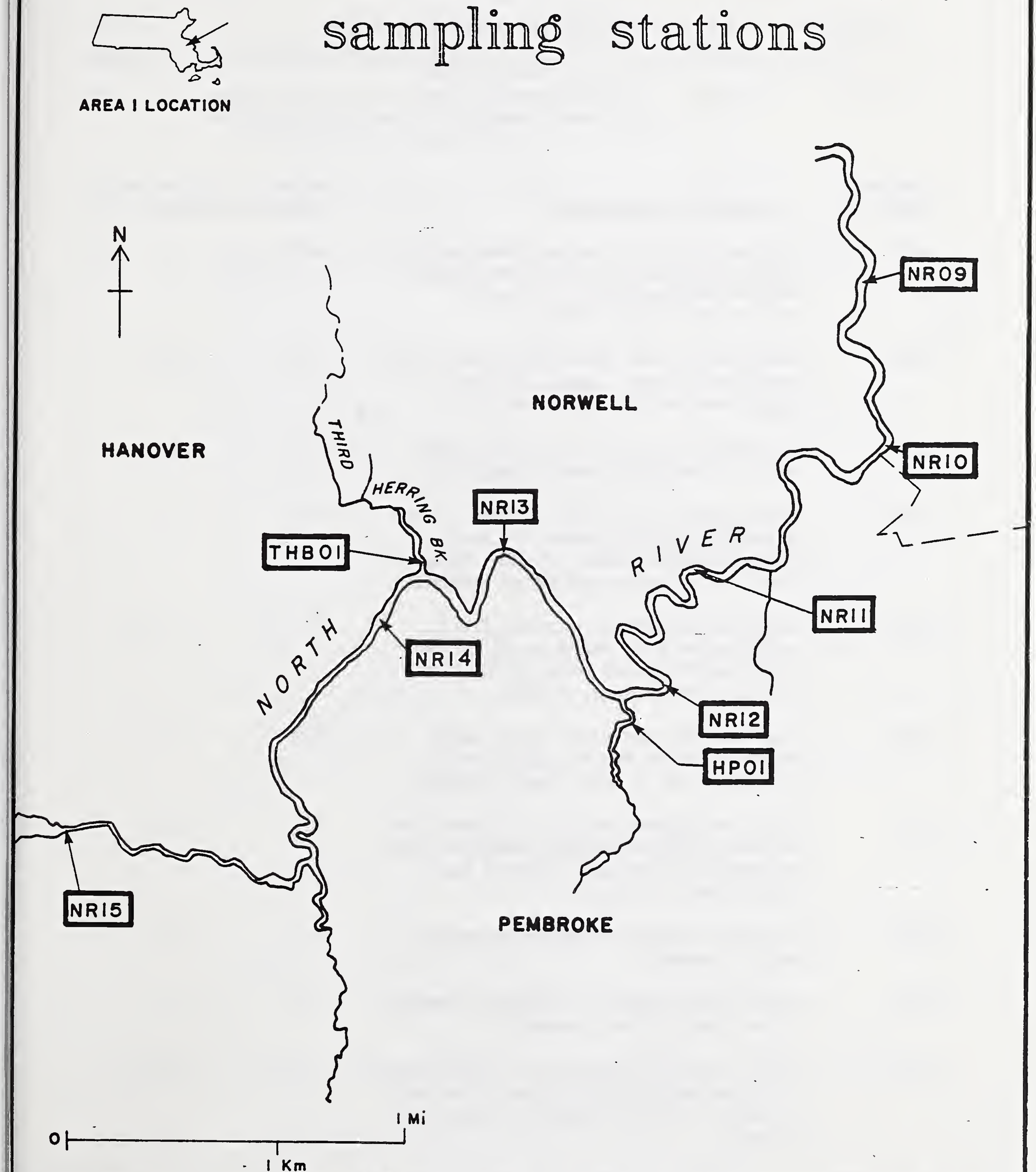


TABLE 3

LOCATION OF SAMPLING STATIONS

NORTH RIVER

AREA II

Station Number	Location Description	Mile Point	Kilometer Point
DW01	Confluence of the natural channel from "Dwelleys Creek" and the North River, sampled approximately 10 yards west of the river, Norwell	6.7	10.8
NR08	Midstream of the straight channel from "Dwelleys Creek", approximately 10 yards west of the river, Norwell	6.5	10.5
NR07	East side of the river at the south fork of Corn Hill Lane, Marshfield	6.2	10.0
NR06	West side of the river at Wanton Lane, approximately 180 yards south of Second Herring Brook, at the former site of the Warham Shipyard, Norwell	5.9	9.5
SHB01	Midstream of Second Herring Brook, approximately 60 yards north of the river at the first bend in the brook off Chittendon Lane, Norwell	5.3,0.2	8.5,0.3
NR05	East side of the North River below Second Herring Brook, approximately 30 yards east of Hill Lane, Norwell	4.8	7.7
NR04	Collected approximately 100 yards upstream of Kings Landing, sampled along the shore on the east side of the North River, Norwell	3.7	6.0
NR03	At Kings Landing, sampled along the shore, Norwell	3.5	5.6
NR02	Below Kings Landing, sampled midstream of the North River, Norwell	3.4	5.5
SB01	North side of Stony Brook, approximately 30 yards north of the river, just upstream of the first bend in the brook, Norwell	3.1,0.0	5.0,0.0

TABLE 3 (CONTINUED)

Station Number	Location Description	Mile Point	Kilometer Point
CB01	East side of Cove Brook, approximately 50 yards upstream of the confluence with the North River, Marshfield	3.1,0.0	5.0,0.0
SD03	Storm drain at Riverside Circle, Marshfield	3.1	5.0
SD01	Storm drain at Mary's Landing, Marshfield	2.1	3.4

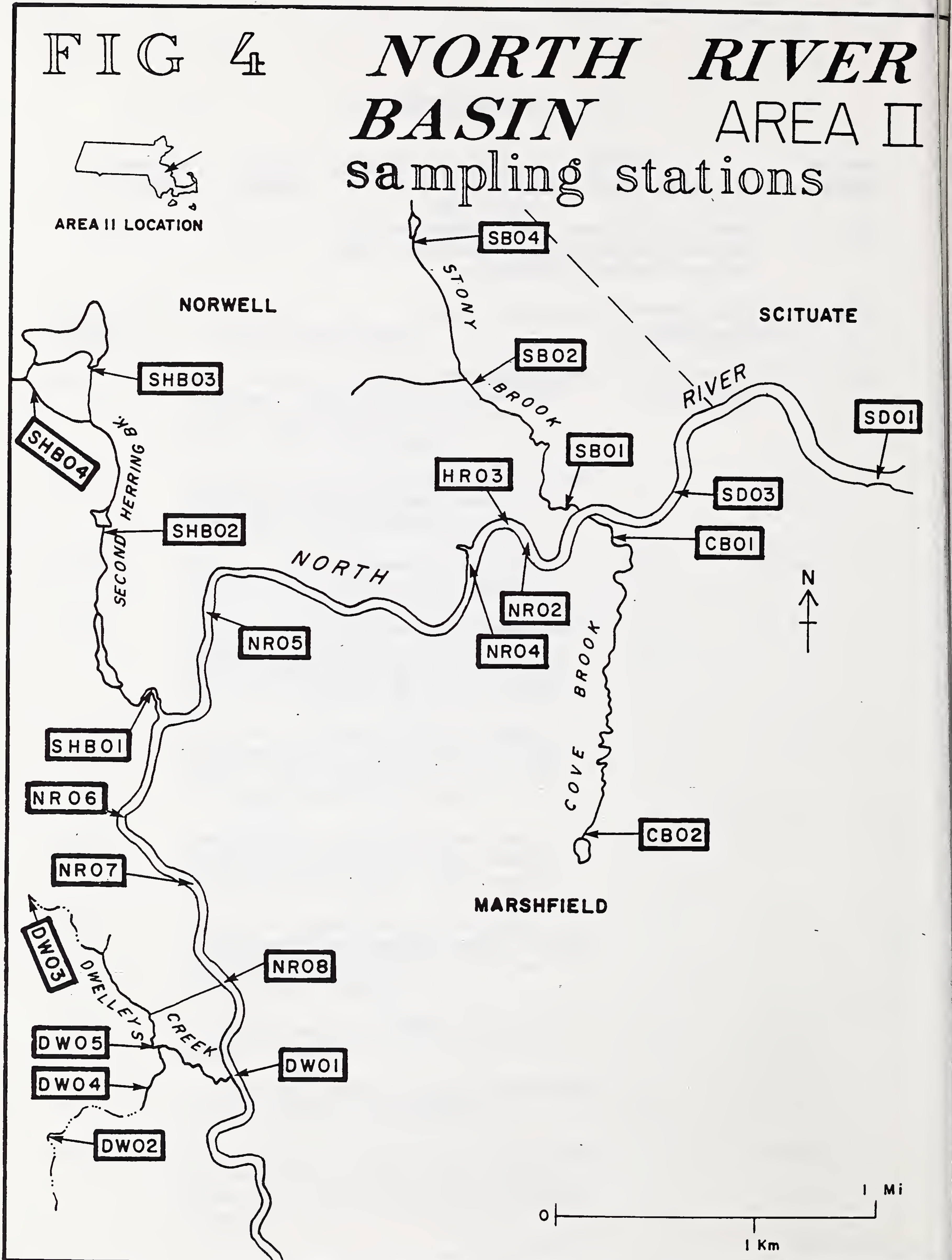


FIG 4
NORTH RIVER BASIN AREA II
sampling stations
AREA II LOCATION
NORWELL
SCITUATE
MARSHFIELD
STONY BROOK
RIVER
NORTH
SECOND HERRING BK.
COVE BROOK
DWELLEY'S CREEK
SB04
SB02
SB01
SHB03
SHB04
SHB02
SHB01
HR03
SD01
SD03
CB01
CB02
NR02
NR04
NR05
NR06
NR07
NR08
DW03
DW05
DW04
DW01
DW02
N
0
1 Mi
1 Km

TABLE 4

LOCATION OF SAMPLING STATIONS

NORTH RIVER

AREA III

Station Number	Location Description	Mile Point	Kilometer Point
NR01	Midstream of the North River, sampled just downstream of Route 3A bridge, Scituate	1.8	2.9
WI01	North side of the North River just below Route 3A bridge, upstream of Wills Island, sampled along shore, Scituate	0.8	1.3
WI02	North side of the North River, below Route 3A bridge, approximately 30 yards east of the eastern most building off Wills Island, Scituate	0.16	0.03
NR00	Near the mouth of the North River on northern side just northwest of the sand spit extending into New Inlet, Scituate	0.7	1.1
FH01A	At the first major tributary to the North River east of the Herring River, at its confluence with the North River, Scituate	0.9,0.0	1.4,0.0
FH02A	Same tributary as in FH01A, sampled approximately 50 yards upstream, Scituate	0.9,0.2	1.4,0.3
FH03A	Midstream of the tributary sampled approximately 80 yards upstream, Scituate	0.9,0.2	1.4,0.3
FH04	Midstream of the Herring River, approximately 100 yards north of its confluence with the North River, Scituate	1.1,0.0	1.8,0.0
FH01	Midstream of a tributary to the Herring River, approximately 5 yards north of its confluence with the Herring River, in a channel leading from the Scituate Wastewater Treatment Plant, Scituate	0.3,0.04	0.5,0.06

TABLE 4 (CONTINUED)

Station Number	Location Description	Mile Point	Kilometer Point
FH02	South side of the tributary sampled in FH01 approximately 60 yards upstream, at the second bend in the tributary, Scituate	0.3,0.12	0.5,0.2
FH03	Midstream of the tributary sampled in FH01 approximately 150 yards upstream, Scituate	0.3,0.4	0.5,0.6
FH05	Midstream of Herring River approximately 10 yards upstream from the channel sampled in FH01, Scituate	0.7,0.3	1.1,0.5
FH06	Midstream of Herring River approximately 150 yards east of Bear Island, approximately 200 yards northeast of Wills Island, Scituate	0.7,0.5	1.1,0.8
SM01	Midstream of Herring River, approximately 25 yards downstream of Simm's Marina (now James Landing Marina), Scituate	0.7,1.1	1.1,1.8
SM02/FH07	Between the slipway at Simm's Boatyard (now James Landing Marina), Scituate	0.7,1.3	1.1,2.1
SM03	Between a slipway at Simm's Boatyard and the shore, sampled next to "James Landing Condominiums", Scituate	0.7	1.1
SM04	Midstream of Herring River, approximately 35 yards upstream of Simm's Boatyard (now James Landing Marina), Scituate	0.7,1.4	1.1,2.3
FH08	Upstream side of the Driftway, at Herring River, Scituate	0.7,1.5	1.1,2.4
SD02	Storm drain at downstream side of the Driftway at Herring River, Scituate	0.7,1.5	1.1,2.4
FH09	Outlet of Old Oaken Bucket Pond approximately 100 yards upstream of FH08, Scituate	0.7,1.6	1.1,2.6

FIG 5 *NORTH RIVER BASIN* AREA III

sampling stations

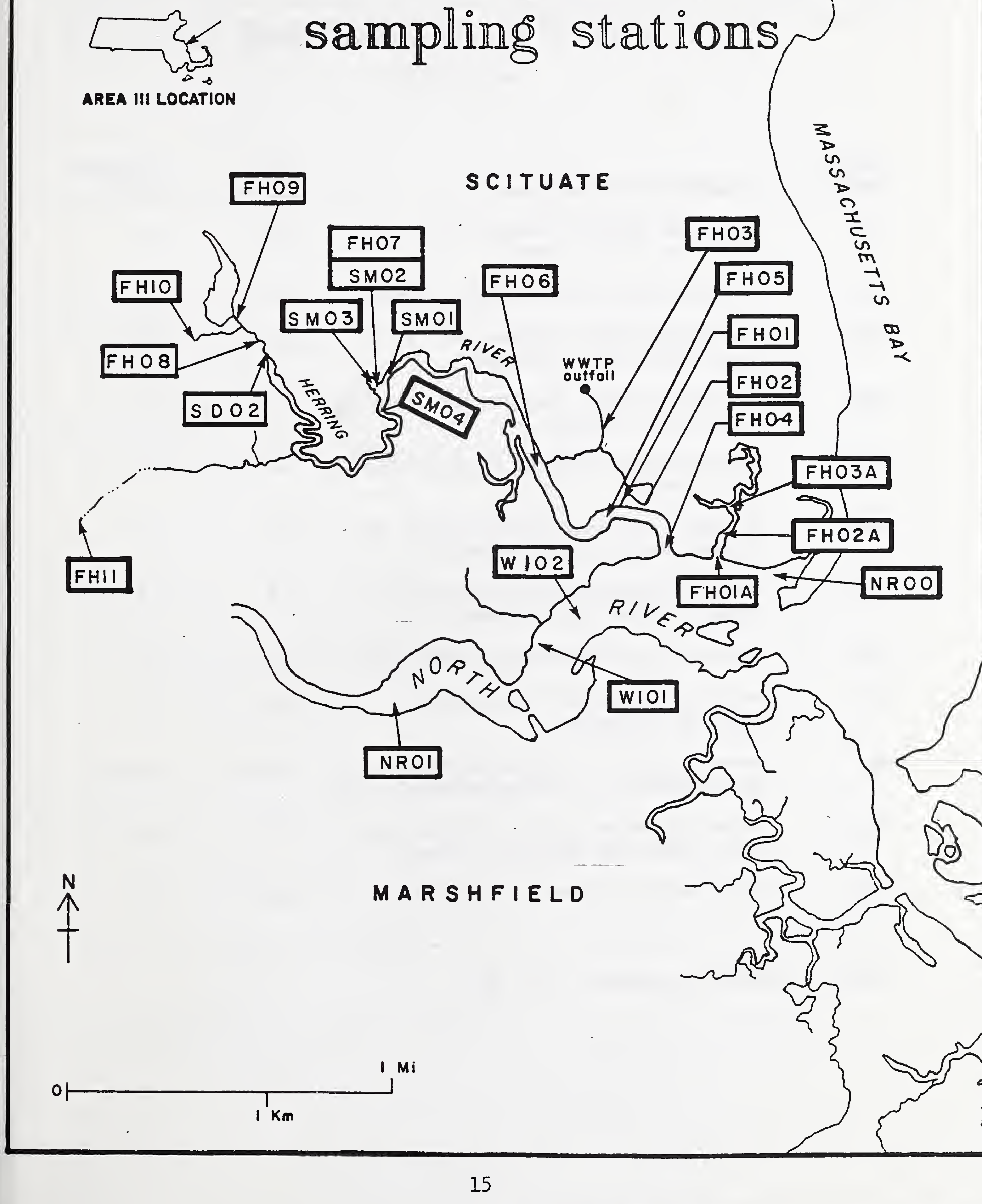


TABLE 5

LOCATION OF TRIBUTARY SAMPLING STATIONS

NORTH RIVER*

Station Number	Location Description	Mile Point	Kilometer Point
DW02	"Dwelleys Creek" at Shrine Rd. off of Riverside Circle, Norwell	0.8	1.3
DW03	"Dwelleys Creek" at Green St., Norwell	0.8	1.3
DW04	"Dwelleys Creek", southern end of Island View Circle, Norwell	0.4	0.6
DW05	"Dwelleys Creek", northern end of Island View Circle, Norwell	0.3	0.5
SHB02	Second Herring Brook at Dover and Main Sts., Norwell	0.4	0.6
SHB04	Tributary to Second Herring Brook, at Central and Mill Sts., Norwell	0.8	1.3
SHB03	Outlet of Torrey Pond, a tributary to Second Herring Brook, Norwell	0.8	1.3
CB02	Cove Brook at Highland St., Marshfield	1.2	1.9
FH10	Herring River at PJ's Restaurant, Route 3A, Scituate	1.58	2.5
FH11	Unnamed tributary to Herring River at Neilgate St. on Scituate-Norwell line	0.5,0.8	0.8,1.3
SB04	Outlet of unnamed pond, a tributary to Stony Brook near Cross St., Norwell	1.12	1.8
SB02	Stony Brook at Route 123, Norwell	0.84	1.4

* Refer to Figures for Areas I, II, III

resuspension of particulates can contribute bacteria and nutrients to overlying waters and changes in redox potential can also release nutrients from the sediments. Direct discharge of bacteria and nutrients to the North River and its tributaries can occur via birds, fish and discharge of marine sanitation devices by boat owners.

LABORATORY MATERIALS AND METHODS
BACTERIA

Membrane Filtration

Depending upon the source of water, different volumes of water samples were passed through pre-sterilized membrane filters (HA type; Millipore, 0.45 um pore size). If the sample volume was insufficient to provide an even distribution of bacteria on the filters then phosphate buffered $MgCl_2$ solution was first added to the funnels and the sample was added in turn to ensure accurate colony counts. Filter holders and funnels were sterilized for two minutes in an ultraviolet sterilizing apparatus. Counts were recorded as colony forming units/100 ml or CFU/100 ml.

Recovery Media

The following Difco media were prepared and used according to the manufacturers instructions and those included in Standard Methods for the Examination of Water and Wastewater, 1985: mFC, mTEC, EC. The modified ME medium was prepared and used according to Dufour (1980).

The PSE medium (Gibco, Inc.) for growth of fecal streptococci bacteria was prepared according to the manufacturer's instructions. Both fecal coliform membrane and MPN tests were run at certain stations. The mFC, mTEC and mE, PSE, were used in membrane filter procedures.

Incubation Periods

The PSE plates were incubated for 48 hours at 35|C (Lab-Line Environette). The mFC plates were sealed in watertight plastic bags (Whirlpac) and incubated in 44.5|C water bath incubator (Blue M or GCA precision scientific) for 24 hours. The mTEC plates were incubated for a two-hour resuscitation period at 35|C (Lab-Line Environette) and then sealed in watertight plastic bags (Whirlpac) and transferred to a 44.5|C water bath incubator for 24 hours. The mE plates were incubated at 41|C for 48 hours (Blue M).

Source Differentiation of Fecal Streptococci

A representative amount of characteristic colonies growing on PSE media were picked and streaked onto BHI agar slants (Difco) for source differentiation. Colonies were differentiated according to their sources, i.e., warmblooded animal, bird, insect, and vegetation (see Figure 2). The methods used for differentiation were according to U.S. Environmental Protection Agency (1978) and included the following tests: growth at 45|C, growth at 10|C, catalase production, starch hydrolyses, lactose fermentation, growth in 6.5 percent methylene blue in milk and peptonization of litmus milk.

Quality Control

For purposes of quality control duplicate samples were collected and analyzed on a predetermined schedule. Typically every other week duplicates were analyzed for all tests except the fecal coliform MPN test.

Chemical and Physical Parameters

Samples for chemical and physical analyses were brought to the Lawrence Experiment Station (LES). Table 6 describes analytical methods used at LES.

TABLE 6

ANALYTICAL METHODS USED AT LAWRENCE EXPERIMENT STATION

PARAMETER	METHOD	REPORTED AS
Suspended Solids	Filtration through standard glass fiber filter paper. Residue dried at 103-105°C. Gravimetric	mg/l S.S.
Total Kjeldahl Nitrogen	Acid digestion using Technical BD-40 Block digester. Colorimetric analysis (reaction of ammonia, sodium salicylate, sodium nitroprusside, and sodium hypochlorite in buffered alkaline medium) using Technicon Auto Analyzer II	mg/l TKN
Ammonia-Nitrogen	Phenate method, automated. Colorimetric analysis using Technicon Auto Analyzer II	mg/l NH_3-N
Nitrate-Nitrogen	Hydrazine reduction method, automated. Colorimetric analysis using Technicon Auto Analyzer II	mg/l NO_3-N
Total Phosphate	Acid digestion using Technicon BD-40 Block Digester. Ascorbic acid reduction colorimetric method using Technicon Auto Analyzer II	mg/l P
Conductivity	Wheatstone bridge type meter. Yellow Springs Instrument conductivity bridge. Model 31	µmhos/cm
Chloride	Argentometric (titration with silver nitrate)	mg/l Cl
Hardness (Ca+Mg)	Atomic Absorption Spectrophotometry. Air-acetylene flame. Perkin-Elmer Model 403	mg/l
Turbidity	Nephelometric. Hach Turbidity meter. Model 2100A	Nephelometric Turbidity Units
pH	Electrometric, glass indicator, silver chloride reference	pH units

FIELD METHODS AND MATERIALS

Bacterial samples were collected in sterile glass containers held below the surface of the water (American Public Health Assoc., 1985). Samples for dissolved oxygen analysis were collected in 250 ml BOD bottles. Dissolved oxygen concentrations were determined using Azide modification of the Winkler method. Percent saturation was calculated from a standard oxygen solubility table.

Nutrient and chemical samples were collected in half-liter bottles which were rinsed twice with sample water and then filled to the shoulder of the bottle. Nutrient samples were fixed in the field with 2 ml of concentrated sulfuric acid. Nutrient samples were analyzed for total phosphorus, Kjeldahl-nitrogen, ammonia-nitrogen and nitrate-nitrogen. Samples were also analyzed for hardness from the same bottle. A second unfixed bottle was used for the analysis of chloride, suspended solids and turbidity.

The pH was determined in the field using a Great Lakes Instruments Digital pH Meter that was calibrated before use and then rechecked periodically.

All samples, except dissolved oxygen, were placed in coolers containing ice and brought to the Lawrence Experiment Station for analysis. All samples were delivered to LES within the six-hour holding period for the bacterial samples and were analyzed upon arrival.

SPECIES AND SOURCE DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

Fecal streptococci are defined as those species of streptococci bacteria which are recovered from feces in significant quantities (Clausen et al., 1977). Speciation of the fecal streptococci and/or grouping of species into types of pollution sources provides some useful information regarding nonpoint sources of fecal contamination. There are several ways in which the data could be used, although currently the Division's only using two methods.

The fecal streptococci results from several sampling stations located in relatively close proximity to one another can be grouped and these pooled data can be used to describe the major types of sources to an area. This is the primary way that the data are currently being used. By this analysis an area can be described as chiefly impacted by warmblooded animals or livestock or birds, etc. Comparisons could be made of seasonal data and/or one area's results could be compared to others.

The results from individual stations can also be described. Fecal streptococci counts are typically very low at individual stations; this situation does not provide very good information. However, when the counts are high enough it is helpful to be able to locate where the fecal streptococci counts increase and/or where the assemblage changes.

If species are isolated it can be determined if S. faecalis or S. faecium is the predominant fecal streptococci. According to Wheater et al. (1979), S. faecium is usually more prevalent in the feces of humans, cattle, pigs, hens and ducks, while S. faecalis is often predominant in the feces of rodents and other small mammals. If more species work is done this information may prove useful in future studies.

Another possible way of interpreting the streptococci genera is to isolate all the streptococci genera and then compare enterococci to non-enterococci totals. Enterococci are present in much greater numbers in human waste (Rutkowski and Slogren, 1987) than in waste from other warmblooded animals.

RESULTS AND DISCUSSION
AREA I

Microbial Results and Discussion

June 29, 1987:

At this early summer sampling, bacterial densities at Area I, were not significant compared to later in the summer. Area I extends from Curtis Crossing, Norwell to just above "Dwelleys Creek". This pretty stretch of river has extensive freshwater marshland. Thus, development does not extend to the banks of the river, but it does extend to the wetlands adjacent to the river. The marshland can either intercept or contribute nutrients or bacteria. Neither function is well delineated.

The microbial indicators sampled were fecal coliform bacteria, fecal streptococci bacteria and Escherichia coli. E. coli was included in this sampling to provide information on the bacterial indicator suggested for use by the U.S. EPA at freshwater contact recreation areas (US EPA, 1986). Although the North River is tidal up to Curtis Crossing, and is classified SB water, it is still basically freshwater flow. The chloride ranged from 48 to 970 mg/l as measured on an ebb tide (Table A-17).

Water monitored at NR15 (Curtis Crossing) had low fecal coliform counts (10 colony forming units or CFU/100 ml) (Table A-15). The tributaries also had relatively low fecal coliform densities at their confluence with the North River, i.e., Third Herring Brook - 20 CFU/100 ml, 30 CFU/100 ml; outlet of Howard Pond - 20 CFU/100 ml, 80 CFU/100 ml. The fecal coliform densities did begin to increase between stations NR12 and NR11. The fecal coliform values at NR12 were 40 CFU/100 ml and 60 CFU/100 ml and NR11 were 100 CFU/100 ml and 120 CFU/100 ml. The bacterial counts remained at the level of NR11 down to NR09 below the Mounce Pond outlet. Duplicates analyzed for fecal coliform bacteria were 160 CFU/100 ml. BSC Group, Inc. (1987) found elevated bacterial counts at this part of the river (their location NR13 - Mounce Pond Tributary) with a peak in June. They suggest that subsurface disposal practices and/or illegal dumping of septage, may be affecting Mounce Pond water quality.

The timing of the peak in fecal coliform bacteria that was found by BSC Group, Inc. coincided with an influx of seasonal residents. Since these residents often have their septic systems pumped out prior to summer use there should be an increase of septage hauled to local treatment plants. Because there were reports of sewage slicks on the river the possibility exists that some of the septage was being illegally dumped into the river. Although DWPC data did not confirm this occurrence, an increase of fecal coliform bacteria was found in this area. In addition, the fecal streptococci were predominantly contributed by warmblooded animals at stations NR09 and NR10, their contribution was 66.6 percent and 100 percent, respectively (Table A-14). No fecal streptococci bacteria were isolated from vegetation or birds.

August 10, 1987:

Some of the same sampling stations in Area I were resampled on August 10. Bacterial counts had increased greatly since the June sampling (Table A-35). The arithmetic mean of the fecal coliform counts in June was 73 CFU/100; in

August it was 426 CFU/100 ml. There had been some precipitation within the preceding three days as measured at the NOAA station at Cohasset (Table A-3).

Although no precipitation fell on August 7, 0.28 and 0.01 inches of rain fell on August 8 and 9, respectively. Following the sampling, on August 10, 1.62 inches fell, but during the sampling time the conditions were only cloudy. Additional work should be considered to isolate upstream sources of fecal contamination. The fecal coliform count at station NR15, the most upstream station, was 620 CFU/100 ml. None of Hanover is sewered. In 1977, the Metropolitan Area Planning Council published the North and South Rivers Basin: A Preliminary Report which described several environmental problems in Hanover. At that time it was stated that according to local officials many of the more densely settled older sections of town experienced failing septic systems as a result of their construction in areas poorly suited for subsurface waste disposal. Whether during the interim 11 years the increased development had led to degradation of ground and surface water quality at the North River is uncertain and requires additional sampling to determine. The population in Hanover increased from 7862 in 1965 (Dorfman, 1985) to 11,812 in 1987 (personal communication Town Clerk, Hanover).

Eighty-three fecal streptococci colonies from Area I were isolated on August 10 for source differentiation. Of these, 51.8 percent were contributed by warmblooded animals while 43.4 percent were from vegetation (Table A-34).

Water Quality Results and Discussion

June 29, 1987:

There had been a trace of rain over the three days prior to sampling. This was not enough to create the runoff necessary to create the impacts on water quality from the paved areas in Area I. However, runoff from Route 3 and the Route 3 Bridge would be important to evaluate in the future. Nitrate-nitrogen (0.8 mg/l) was higher at Curtis Crossing (NR15) than at station NR09 where it was <0.1 mg/l (Table A-17). Total phosphorus also was higher at Curtis Crossing (0.15) mg/l at NR15 than at NR11 0.08 mg/l.

There was evidence of intense algal productivity at stations THB01 and HP01 since they both had supersaturated oxygen conditions of 110.4 and 137.8 percent, respectively (Table A-16). The turbidity which also may be an indication of phytoplankton was 9.0 NTU at THB01 and 3.2 at HP01 (Table A-18). Periphyton, which could also contribute to the dissolved oxygen concentrations, was not measured.

August 10, 1987:

Nutrient concentrations had remained basically the same in this section of the river since the earlier sampling date on June 29, 1987. The arithmetic mean of total phosphorus had increased from 0.11 mg/l to 0.16 mg/l in August (Table A-37). The mean of the total Kjeldahl-nitrogen ranged from 1.09 mg/l to 1.19 mg/l, with the slight increase in August.

Nutrient concentrations entering Area I at station NR15 could contribute to algal production downstream. Phosphorus (0.22 mg/l) far exceeds the U.S. EPA (1976) recommended criterion of 0.05 mg/l phosphorus to "prevent the develop-

development of biological nuisances and to control accelerated or cultural eutrophication." Although algal production was not measured in these surveys an indication of enhanced algal production is the supersaturated dissolved oxygen conditions present at NR15 (101.8 percent). The phosphorus concentrations were higher in the upstream stations than in the downstream stations and ranged from 0.22 mg/l to 0.14 mg/l. This is evidence that the upstream sources of phosphorus to this area dominate over others and need to be controlled.

The total Kjeldahl-nitrogen showed a lot more variability with peaks at NR13 (1.8 mg/l) and another at NR09 (0.98 mg/l). These do not indicate a major nutrient problem. Ammonia values were all <0.02 mg/l.

CONCLUSIONS - AREA I

- Fecal streptococci bacteria in Area I were primarily contributed by warmblooded animals.

- Fecal coliform counts appeared to increase over the summer months. On June 29, 1987 the fecal coliform range was 20 to 170 CFU/100 ml and on August 10 this range was 160 to 740 CFU/100 ml. Of the two tributaries sampled in this section, HP01, the outlet to Howard Pond, had an elevated fecal coliform count on August 10 of 550 CFU/100 ml.

- Water quality of the North River was slightly degraded at Curtis Crossing, station NR15. Dilution and attenuation of the nutrients contributed to lower downstream concentrations. However, on June 29, 1987 a second area of elevated nutrients was found in the region of NR10 and NR09. This was accompanied by higher fecal coliform counts as well, perhaps emanating from the Mounce Pond area.

RECOMMENDATIONS - AREA I

- Dye testing of the septic systems in the vicinity of Howard Pond and Mounce Pond should be considered; bacterial contamination of the tributary outlets of both these areas was found.

- Although people have observed sewage slicks on the North River within Area I, occasional water quality monitoring would not likely provide much additional information. Instead, future efforts must focus on basin-wide management of the septage haulers to track where they are pumping and where they are delivering their septage.

- Sample below the Route 3 Bridge during or after a major rain event to determine how this major road system impacts the water quality of the North River.

RESULTS AND DISCUSSION - AREA II

Microbial Results and Discussion

Sources along the tributaries are major contributors of fecal coliform bacteria to the North River at Area II. This area extends from the confluence of "Dwelleys Creek" with the North River to just below Kings Landing, Norwell. Several tributaries flow into this area: "Dwelleys Creek", Second Herring Brook, Stony Brook and Cove Brook. There are also two storm drains which flow during dry weather and are also major contributors of fecal coliform bacteria. One of these flows to the North River off of Riverside Avenue in Marshfield and the other was found flowing into "Dwelleys Creek" in Norwell.

The area adjacent to the mainstem of the river is basically salt marsh with some areas of upland vegetation. Kings Landing, a marina with approximately 60 slips, is located in the area and there is a public boat landing at Bridge Street. New unsewered development is rapidly occurring in this area on soils not recommended for subsurface disposal (Metropolitan Area Planning Council, 1977).

June 22, 1987:

On June 22, all of the tributaries sampled were contributing elevated bacterial counts to the North River. These ranged from 840 fecal coliform CFU/100 ml at Stony Brook to 2700 CFU/100 ml at "Dwelleys Creek". Station NR07, located on the opposite bank from NR08, had low bacterial counts (40 fecal coliform CFU/100 ml), but at NR06 they were again elevated (900 CFU/100 ml). This station is located approximately six-tenths of a mile downstream of NR08 along the same bank. Whether this is an indication of a source, or lack of mixing from station NR08 is not yet known. The chloride concentration of 7000 mg/l at NR08, 9500 mg/l at NR07, and 10,000 mg/l at NR06 would suggest that a plume is not just hugging the shore. Station NR06 accepts drainage from a large tidal marsh, as well as, some street drainage off of Corn Hill Lane. The fecal coliform counts in the remaining instream stations decreased with dilution and die-off. At NR02, sampled just below Kings Landing, the fecal coliform count was 100 CFU/100 ml. Stations NR04 to NR02 were a series of stations sampled both above and below Kings Landing and also within a salt marsh area. The fecal coliform counts decreased over this distance from 160 CFU/100 ml to 100 CFU/100 ml. On this sampling date the storm drain just above Kings Landing at the end of Neilgate Road was not sampled. There have been some reports of continual flow from this pipe even during dry weather thus suggesting the possibility of a cross-connection or infiltration.

Species differentiation of the fecal streptococci bacteria was done on this date on 45 fecal streptococci colonies isolated from the stations within area II. S. faecium, which is the predominant species contributed by humans, but also prevalent in the feces of cattle, pigs, domestic fowl and ducks, represented 40 percent of the fecal streptococci isolated. Stations NR08, SD03, and DW01 were dominated by S. faecium bacteria (Table A-9).

July 20, 1987:

Several new sampling stations were included in the July 20 sampling effort. Additional stations were included in the tributaries in an attempt to locate the sources of the high fecal coliform counts identified during the June 22 sampling. Sampling stations were to be located where roads cross "Dwelleys Creek", Second Herring Brook and Stony Brook; sampling sites also included stations extending up to the headwaters. However, the dry weather which was experienced throughout most of July when only 0.05 inches of rain fell over the ten days prior to sampling, resulted in dry stream bed conditions at several upstream stations (Table A-2).

Most fecal coliform counts were lower on this date than on June 22. An area of concern was found at Shrine Road, Norwell (DW02). This station receives discharge from a storm drain located on the upstream side of "Dwelleys Creek." This storm drain was flowing on this date and an oil sheen was present on the water's surface. The fecal coliform count here was 600 CFU/100 ml; sampling further downstream at DW01, the confluence of "Dwelleys Creek" and the North River did not indicate any additional sources of fecal coliform bacteria. The count here was 180 CFU/100 ml (Table A-25).

No problem areas in the four stations that were sampled were isolated in the Second Herring River basin. The fecal coliform range was 20 CFU to 140 CFU/100 ml. Station SHB02 at Dover and Main Street accepts the runoff from a small commercial area. Runoff from paved surfaces often contributes high fecal coliform counts as well as nutrients. This area should be resampled during a rain storm event to determine what, if any, water quality impacts are found.

Station SB02 on Stony Brook also needs further investigation. This station located at Route 123 in Norwell had a fecal coliform count of 1280 CFU/100 ml. No stations were sampled upstream because of lack of flow on this date. Nine fecal streptococci colonies from SB02 were tested for source differentiation; six were contributed by warmblooded animals, one by vegetation, and two were non-fecal streptococci.

Runoff from nonpoint sources of fecal contamination had not contributed fecal matter to Stony Brook. No rain had occurred since July 15 when 0.05 inches of precipitation had fallen as measured at the National Oceanic and Atmospheric Administrative Office in Cohasset. Prior to that only 0.02 inches had fallen on July 9. A sanitary survey of this area would indicate if any pipes drain into this area or if livestock frequently cross or pasture on the banks of Stony Brook. A possible seasonal problem is evident. This station was again sampled on December 7, 1987 and the fecal coliform counts were reduced (i.e., 20 CFU/100 ml).

High fecal coliform densities were also noted at SD03, the storm drain off Riverside Circle, Marshfield. The collection system for this drain extends up a steep hillside. The drain itself is located on the edge of the salt marsh. SD03 was sampled approximately five feet from its entry into the marsh. The fecal coliform count was 900 CFU/100 ml.

Six fecal streptococci colonies were isolated from SD03, five were from warmblooded animals and one was non-fecal streptococci. Twenty-seven fecal streptococci colonies were tested from Area II on July 20; of these 66.7 percent were from warmblooded animals, 22.2 percent vegetation and 11.1

percent non-fecal streptococci (Table A-24).

August 17, 1987:

Area II was sampled for the third time on August 17 and once again sampling stations were included on the tributaries. No precipitation had occurred since August 11 when 0.02 inches fell in Cohasset (Table A-3). Even with the dry conditions, the storm drain at SW02 was flowing, albeit a trickle on this date. The fecal coliform count at DW02 was elevated with 1100 CFU/100 ml (Table A-40). By the next station downstream DW04, which is located at the southern end of Island View Circle and below a small pond area with ducks, the counts had decreased to 160 CFU/100 ml. At DW05, at the northern end of Island View Circle, Norwell, a further decline in the fecal coliform counts had occurred. They were now 20 CFU/100 ml. This station is located at the edge of the tidal marsh.

At DW01, the next downstream station, the fecal coliform counts had increased to 420 CFU/100 ml. The source is unaccounted for and may indicate multiplication of fecal coliform or addition from wastes deposited on the marshland. The fecal streptococci bacteria did not show a similar level of increase.

Stony Brook again had a peak in the fecal coliform count at station SB02 at Route 123. The fecal coliform count there was 320 CFU/100 ml. A drainage gully leading from a horse barn intersects Stony Brook above Route 123 and may contribute to these counts. The next station upstream (SB04) had a fecal coliform count of 20 CFU/100 ml, station SB01 at the confluence of Stony Brook and the North River, 40 CFU/100 ml.

Only 22 fecal streptococci bacteria were measured from Area II on August 17. Nine of these colonies were isolated from the SB02 sample of which 82 percent were from warmblooded animals (Table A-39)

Water Quality Results and Discussion

June 22, 1987:

The nutrient concentrations on this date could be considered moderate. The average total Kjeldahl-nitrogen for this area was 1.25 mg/l and the average ammonia concentration was 0.5 mg/l (Table A-12). Ammonia represented 40 percent of the total Kjeldahl-nitrogen. For comparative purposes, on June 29 in Area I, six percent of the TKN was ammonia.

Total phosphorus ranged from 0.07 to the highest mainstem instream value of 0.11 mg/l at NR07. This station is located off Corn Hill Lane, Marshfield at Second Herring Brook (SHB01). The percent oxygen saturation (56.6 percent) was low at station SB01. The dissolved oxygen concentration at this site was 4.9 mg/l at 17°C (Table A-11). This does not meet the Class SA criteria of a minimum of 6.0 mg/l at water temperatures of 25°C or below (MDWPC, 1985). The lowest mainstem percent saturation was 62.5 percent at NR07, again the SA water quality criteria would not have been met (see Table 1).

July 20, 1987:

The average total phosphorus concentration in Area II did not increase from the June 22 sampling (Table A-27). The average total Kjeldahl-nitrogen decreased from 1.25 mg/l on June 22 to 0.90 mg/l on July 20 as had the average ammonia from 0.5 mg/l on June 22 to 0.13 mg/l on July 20.

Station SD03, the storm drain at Riverside Circle, had the highest phosphorus concentrations on both sampling dates. On June 22 it was 0.24 mg/l and on July 20, 0.22 mg/l. At DW02, "Dwelleys Creek" at Shrine Road, Norwell the nutrient concentrations were also elevated with total phosphorus 0.18 mg/l, ammonia 0.27 mg/l and total Kjeldahl-nitrogen 1.3 mg/l. These conditions can lead to algae growth downstream.

Turbidity (37 NTU) at station DW02 and suspended solids (52 mg/l) (Table A-28) can also have important biological impacts on the stream. According to the Canadian Council of Resource and Environment Ministers (1987) suspended solids should not exceed 25 mg/l in order to avoid adversely impacting the benthic biota. These impacts may include: preventing the successful development of fish eggs and larvae; reducing food available for fish by reducing the light available for photosynthesis by algae and macrophytes (U.S. Environmental Protection Agency, 1976).

At station DW01 turbidity and suspended solids values had decreased to 2.6 NTU and 10 mg/l, respectively. Total phosphorus also showed this decrease as a result of dilution and attenuation and ranged from 0.18 mg/l (DW02) to 0.08 mg/l (DW01). The concentration of total Kjeldahl-nitrogen also declined but not as much as other parameters from 1.3 mg/l (DW02) to 1.0 mg/l (DW01). Ammonia increased in concentration from 0.27 mg/l (DW02) to 0.62 mg/l at station (DW01).

Station DW01 is located at the confluence of "Dwelleys Creek" and the North River and is actually within the intertidal marsh area. This station can receive organic material that was previously deposited further upstream and then transported to the area, and some can also be deposited by receding tidal waters. Which phenomenon is occurring here and in other areas of the North River can not be established at this time. Bowden (1982) showed that the tidal marshes of the North River appear to be sinks for nutrients rather than exporters of nutrients. This is in contrast to other studies which found nitrogen and phosphorus being contributed by marshes (Odum, 1984). Another example is two stations from the other branch of "Dwelleys Creek" sampled on July 20. Station DW03 (Green Street, Norwell) is the upstream station and NR08 is at the confluence of the straight channel of "Dwelleys Creek" with the North River, this station is located within the intertidal marshland. The total phosphorus concentration went from 0.13 mg/l (DW03) to 0.09 mg/l at NR08, TKN increased over this distance from 0.73 mg/l to 2 mg/l and ammonia did as well (0.05 mg/l to 0.12 mg/l).

August 17, 1987:

Besides elevated bacterial counts at "Dwelleys Creek" (DW02) at Shrine Road, Norwell, high concentrations of nutrients were also present, i.e., TKN (2.5 mg/l), ammonia (1.3 mg/l) and phosphorus (0.53 mg/l) (Table A-42). Further downstream the stations show the effect of attenuation and/or dilution until DW01, at the confluence with the North River, which again shows slightly higher

nutrient concentrations than DW05. It can not be determined from this work if this is a result of the river water quality, contributions from the tidal marsh, and/or sample variability.

CONCLUSIONS - AREA II

- The tributaries in this area of the North River, in particular, "Dwelleys Creek" and Stony Brook have bacterial problems that are evident during dry weather. Station DW02 ("Dwelleys Creek" at Shrine Road) is impacted by a storm drain which flows during dry weather and Stony Brook has one area impacted by agricultural runoff.

- Stony Brook exhibited a peak in fecal coliform counts at SB02, Stony Brook at Route 123 which may have been caused by agricultural runoff.

- The Class SA dissolved oxygen standard was not always attained in Area II. Areas of greatest concern are at the confluence of the tributaries with the North River where often the 6.0 mg/l at water temperatures 25°C and below was not attained. It is not known from this sampling if this is the result of natural conditions or from the oxidation of solids that are deposited in the tributaries by runoff or storm drainage.

- The storm drain at Riverside Circle, Marshfield and also DW02 ("Dwelleys Creek" at Shrine Road, Norwell) are important sources of nutrients.

- The nutrient contributions to the North River from the tidal marshland can not be determined from these data.

- The North River Commission Director, Janet O'Brien, has hired a consultant to develop a plan of action to correct some of the problem storm drainage systems to the North River. This should have a favorable impact on the water quality in Area II. Since initiation of this study, improvement of storm drainage systems at Riverside Circle, Marshfield (SD03) is being overseen by officials from the town of Marshfield.

RECOMMENDATIONS - AREA II

- A sanitary survey should be done in the area of Stony Brook by SB02 to locate the origin of the fecal coliform peak here.

- The storm drainage system at Riverside Circle, Marshfield also has elevated bacterial counts and should be examined further.

- The committees from the North River Commission and local town agencies are actively working to eliminate storm drainage systems which are known to be the cause of fecal contamination to the North River. It is recommended that future efforts focus on ways to reduce the bacterial impacts to the North River from storm drains by sponsoring bylaws requiring retention basins or other innovative methods of storm water disposal.

RESULTS AND DISCUSSION- AREA III

Microbial Results and Discussion

June 15, 1987:

The sampling of the North River began with Area III on June 15. This area is chiefly salt marsh and includes the Herring River watershed. Located on the perimeter of the marsh are several residential areas, and a new large condominium complex, James Landing which includes what was formerly Simm's Boatyard. Several storm drains lead into the marsh which also accepts the discharge from the Scituate Wastewater Treatment Plant. The marsh is also believed to have a large gull population present, at least seasonally. The area is used by sport fishermen and boaters. No swimmers or bathers were observed during the site visits.

On June 15 the fecal streptococci bacteria were differentiated to species. Area III had 33.3 percent S. faecalis var. zymogenes and 11.1 percent from S. faecium (Table A-4). These are both considered to have warmblooded sources. S. faecalis var. liquefaciens constituted 55.6 percent of the isolated fecal streptococci bacteria. Using the EPA (1978) scheme for source differentiation, these streptococci would be listed as an insect source. S. faecalis var. liquefaciens can also be contributed by warmblooded animals. Clausen et al. (1977) considered S. faecalis var. liquefaciens to be ubiquitous. For the interpretation of this report, S. faecalis var. liquefaciens is considered as an indication that runoff from mixed nonpoint sources has occurred including those contributed by insects.

The ratio of S. faecium to S. faecalis colony counts from this area (i.e., 11.1:88.9) is an indication that lower animals are dominating in contributions. This could include dogs, cats, and muskrats and other rodents. Low numbers of fecal streptococci colonies were isolated on this date. FH08 was an exception with a total of six colonies contributed by S. faecalis var. liquefaciens (two colonies) and S. faecalis zymogenes (four colonies). Again S. faecalis var. liquefaciens may be from insects and or runoff either contributed directly to the waterbody or via infiltration to a storm drain system. S. faecalis var. zymogenes are contributed by warmblooded animals.

July 7, 1987:

Area III was again sampled on this date which was a partly cloudy day. Over the preceding three days there had only been 0.01 inches of rain recorded at the NOAA station in Cohasset. The range of the fecal coliform colony counts was <5 to 840 CFU/100 ml (Table A-20). Fecal coliform densities were highest at FH03 (840 CFU/100 ml) and FH08 (160 CFU/100 ml).

Nineteen colonies were tested from this area for source differentiation of the fecal streptococci bacteria, 84.2 percent were from vegetation, 10.5 percent warmblooded animals and 5.3 percent non-fecal streptococci (see Table A-19).

August 3, 1987:

Area III was again sampled on an outgoing tide on August 3, 1987. The weather was rainy, 0.29 inches fell beginning around midnight and ending around noon (Table A-3). Duplicates of the bacterial samples were collected and analyzed. This provided a way of examining the variability of the bacterial counts instream. Also, on this sampling date, some additional stations were added which were located below and within the slipways of Simm's Boatyard (now called James Landing).

Data from stations SM01 and SM04, near James Landing, gave inconclusive results about the impact that the marina has on water quality. This confusion was caused in part by the large sample variability of the fecal coliform counts on this date. Results from two sets of samples were not used because of possible laboratory error. The results from SM04 were not used. Unfortunately, this would have provided information about conditions upstream of James Landing. The nearest upstream station sampled on this day was FH09, the outlet of Old Oaken Bucket Pond. The fecal coliform count here was 100 CFU/100 ml. The fecal coliform counts collected within the slipways at James Landing were all high with a range of 1100 to 2020 CFU/100 ml. Source differentiation of the fecal streptococci bacteria collected around the slipways at James Landing were predominantly contributed by warmblooded animals (see Table A-29). Out of 49 fecal streptococci colonies analyzed from stations SM01 to SM04, 40 (81.6 percent) were contributed by warmblooded animals. Further work is necessary in order to determine whether this fecal contamination is contributed at this site or upstream or downstream of the boatyard. According to Ray Gaffey of Simm's boatyard, now James Landing, a pump-out facility has been installed at this boatyard which was to become functional during the summer of 1988. Future work should include investigation of upstream sources and determination of time-of-travel, and amounts of tidal water exchanged on each tide. There is no doubt that some large source of fecal contamination exists.

On August 3, rain fell during the sampling time. It is difficult to assess if the 0.29 inches of precipitation which began to fall at midnight contributed to the high fecal coliform counts in the Herring River. However, at the two storm drains sampled in Area III on August 3, one had a low fecal coliform density (SD01, <10 CFU/100 ml), while the storm drain at Mary's Landing, Marshfield (SD02) had an average fecal coliform density for two replicates of 3850 CFU/100 ml. On July 7, with no previous rain having fallen before sampling, SD01 had <5 FC CFU/100 ml and SD02 the same. But, on June 15 when 0.49 inches had fallen the day previous to sampling SD01 had 10 FC CFU/100 ml and SD02 140 FC CFU/100 ml.

Water Quality Results and Discussion

June 15, 1987:

Area III of the North River is within an area classified SA by the Division of Water Pollution Control. Only one station (FH07) did not meet the dissolved oxygen standard of 6.0 mg/l, but two stations had over 100 percent saturation (FH03, FH02). FH03, on the Herring River, is located just below the Scituate Wastewater Treatment Plant and FH02 is located approximately 50 yards below FH03. The super saturated conditions may have been caused by algae; however,

no measurement of the algal production was made. The nutrients were available for algal growth, however (total Kjeldahl-nitrogen: 6.4 mg/l; ammonia: 0.39 mg/l; and total phosphorus: 2.1 mg/l) (Table A-7).

At James Landing (FH07) abundant nutrients were present, e.g., total Kjeldahl-nitrogen (TKN) was 5.8 mg/l, ammonia 0.13 mg/l and phosphorus 0.2 mg/l. The elevated concentrations of TKN at stations FH03 and FH07 may have been contributed by algae or waste products from humans and animals.

From the available data it can not be determined to what extent the nutrients are being contributed from the salt marsh and how much is being contributed by sources outside of the salt marsh area which are then washed or drained into the marsh.

Nitrate-nitrogen was elevated at SD02 as was ammonia (i.e., 2.8 mg/l and 0.50 mg/l, respectively). This storm drain flows into the Herring River at the Driftway, Scituate.

<u>July 7, 1987</u>:

Dissolved oxygen at FH03 was low on this date (4.9 mg/l) with only 54.7 percent saturation (Table A-21). This is in marked contrast to June 15 when super saturation levels were measured. Although all samples were collected on outgoing tides, it is probable that on this date, the Scituate Wastewater Treatment Plant had more influence on the sample water quality. Chloride at FH03 was 14,000 mg/l on June 15 but when measured on July 7 it was 5,500 mg/l showing much more influence from freshwater sources (Table A-22). Again, Kjeldahl-nitrogen was highest at this station (2.7 mg/l), ammonia was 1.2 mg/l, and total phosphorus was 2.1 mg/l. The discharge from the Scituate Treatment Plant at the overflow pipe was 35,000 gallons/day on this date (July 7). The storm drain (SD02) again had an elevated phosphorus concentration of 0.33 mg/l. Turbidity was also elevated at this station (5.3 NTU) (Table A-23).

<u>August 3, 1987</u>:

Once again the nutrient contributions measured near the discharge pipe leading from the Scituate Wastewater Treatment Plant were elevated. Total Kjeldahl-nitrogen at FH03 was 4.1 mg/l, ammonia was 0.7 mg/l and total phosphorus was 2.6 mg/l (Table A-32). Monthly records provided by the Scituate Wastewater Treatment Plant for a sample collected August 17, 1987, showed nutrient concentrations of 3.3 mg/l TKN and 6.5 mg/l total phosphorus. Thus, during some sampling times nutrients can even be higher than the concentrations present on August 17. Dilution of the samples leading from the Scituate Wastewater Treatment Plant is evident in the sample series FH03, FH02 and FH01. Total Kjeldahl-nitrogen went from 4.1 mg/l at FH03 to 2.1 mg/l at FH01; ammonia dropped from 0.7 mg/l to 0.45 mg/l. Chloride ranged from 1000 mg/l at FH03 to 10,000 mg/l at FH01. The tidal influence is evident here.

It is likely that the high nutrient values at FH09 are an artifact caused by pieces of vegetation or detrital material in the sample bottle. The turbidity (120 NTU), and suspended solids (4940 mg/l) indicates this is a possibility.

CONCLUSIONS - AREA III

- <u>Warmblooded animals</u> contribute to the <u>seasonal closure</u> of the shellfish beds in the area of the North River by the Herring River.

- The amount of the fecal contamination and nutrient loading contributed by <u>water exchange over the marshlands can not be separated from that contributed by drainage into the intertidal waters</u>. In general, it is known that coastal marshes import dissolved oxidized inorganic forms of nutrients (nitrite, nitrate, phosphate) and export dissolved and particulate reduced forms (ammonium, organic nitrogen, phosphorus compounds) (Odum, 1984).

- On or before August 3, 1987, <u>a large amount of human waste</u> was likely dumped or released into the Herring River. Samples with very high fecal coliform counts were found in the vicinity of James Landing.

- <u>No S. avium bacteria were isolated</u> in these samples which is an indication that during the summer season flocking of birds on the water is not common in this area.

RECOMMENDATIONS - AREA III

- A plan should be devised to monitor the success of the pump-out facility at Simm's Boatyard (James Landing). A tracking system should be established so that it is known which boats are being pumped-out and how often. Because of the lack of regulations governing their installation and use, pump-out facilities are often under-utilized (US EPA, 1985).

- Additional work should be done around James Landing to determine if the very high fecal coliform counts found in this area on August 3, 1987 were an isolated occurrence or from a continuous discharge.

- Further work should be done at SD01, the storm drain at the Driftway, Scituate. This storm drain flows during dry weather and contributes high nutrient and bacterial counts to this area.

- The Division of Water Pollution Control's Technical Services Branch should conduct dye studies in the Herring River to determine time-of-travel and current patterns to aid in locating sources of fecal contamination.

- Intermittent dischargers of fecal contamination are not easily caught and prosecuted. There is an indication of illegal dumping in the Herring River. Some complaints of sewage plumes have been observed on the river (BSC Group, Inc. 1987), but no definite plan has been proposed to deal with the problem of illegal dumping by septage haulers. It is recommended that officials from the watershed towns meet to devise and coordinate a tracking system for septage haulers, so that it will be known what houses are being pumped and where the septage is being disposed.

OVERALL CONCLUSIONS

At the present time the banks of the North River between Curtis Crossing and the Route 3A Bridge are not extensively developed with homes and commercial establishments. This is a result, in part, from the extensive marshlands that are found along the river which preclude the construction of houses. In addition, the Scenic River Protection Order also provides for a corridor 100 yards-wide along both sides of the river (MGL c21S17). The Scenic River Protection Order created by Chapter 367, section 62 of the Acts of 1978, give the North River Commission authority to regulate activity within this corridor. This minimizes development in the protected areas. Even so, the North River, in the area described, does have warmblooded contributors of fecal contamination. This was established by source differentiation of the fecal streptococci bacteria.

There is little agricultural use of the land along the corridor so this can be eliminated as a possible major contributor of bacteria and nutrients. Furthermore, because of the lack of housing on river shores, fecal contamination from septic system leach fields are unlikely to be a major bacterial source to the river except for a few possible isolated cases.

One use of the river which likely resulted in some degree of fecal contamination is the presence of marinas on the North River and the Herring River. Until 1988 no marina in this area had a pump-out facility that would collect the septic waste that is partially treated or untreated in the sanitation devices installed on many boats. James Landing (Simm's Boatyard) in Scituate has installed a pump-out facility which went into operation in 1988. This may help to reduce some fecal contamination to the Herring River. However, Scituate Wastewater Treatment Plant also discharges to the Herring River. This remains a major source of fecal contamination, although the town is developing a facilities plan to correct problems at the plant.

During this sampling very high fecal coliform counts were found in the vicinity of James Landing. It is known that the fecal contaminants were from warmblooded sources but the actual source of what was likely a massive discharge of material could not be determined from these data.

From the source differentiation of the fecal streptococci bacteria it was learned that during the summer months birds are not a primary contributor of fecal contamination to the Herring River.

Although contamination from septic leachate fields is not likely a primary contributor to the mainstem of the river, it is possible that fecal contamination exists in the tributaries to the river particularly "Dwelleys Creek" and Stony Brook.

Besides the Scituate Wastewater Treatment Plant, the other known direct discharges to the North River are from storm drains. Several of these were initially located by BSC Group, Inc. The storm drains with possible leachate infiltration and/or illegal tie-ins are:

- Shrine Road, Norwell - discharges to "Dwelleys Creek";
- Riverside Circle, Marshfield - discharges to the North River;

- o Drain adjacent to Mary's Landing, Marshfield - discharges to the North River; and
- o Driftway, Scituate - discharges to the Herring River.

Limited wet weather sampling was accomplished during the summer of 1987. Potential nonpoint sources of fecal contamination and of nutrients such as paved areas in Norwell Center and in Scituate by the Driftway, and lawn fertilizer from homes along the tributaries could not be assessed.

The vegetation patterns along the river alternate from marshland, either salt marsh (S. alterniflora) or tidally influenced marshland (Phragmites communis), to upland vegetation, wooded areas. Preliminary results indicate that at the confluence of "Dwelleys Creek" and the North River fecal contamination, as well as total Kjeldahl-nitrogen, may increase over the marshland as judged from upland concentrations. Further work needs to be done to verify this phenomena.

Illegal dumpling of septage by septage haulers is reported to have occurred in the North River. It may even have caused the elevated bacterial counts found in the Herring River on August 3. It is strongly recommended that a task force be established by the towns to work towards the establishment of a tracking system of septage waste disposal practices.

Sources of fecal contamination to the North River are elusive and require further investigative work with other chemical or bacterial methods in order to resolve them. The role of the wetland systems in nutrient and bacterial export should be explored further.

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APPENDIX - LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

TABLE A-1

PRECIPITATION DATA AS RECORDED** AT COHASSET, MA.

JUNE, 1987

DATE	PRECIPITATION (inches)	DATE	PRECIPITATION (inches)
1	0	16	0
2	0	17	0
3	0.22	18	0
4	0	19	0
5	trace	20	0
6	0.50	21	0
7	0	22*	trace
8	trace	23*	trace
9	trace	24	0.41
10	0	25	0.02
11	0	26	trace
12	trace	27	trace
13	trace	28	trace
14	0.49	29*	0
15*	0	30	0
		TOTAL FOR MONTH	1.64

* sampling date
** By the National Oceanic and Atmospheric Administration, unpublished memo.

TABLE A-2

PRECIPITATION DATA AS RECORDED** AT COHASSET, MA.

JULY, 1987

DATE	PRECIPITATION (inches)	DATE	PRECIPITATION (inches)
1	0.13	17	0
2	0	18	0
3	0.52	19	0
4	0	20*	0
5	0.01	21	0.05
6	0	22	0
7	0	23	0
8	0.01	24	0
9	0.02	25	trace
10	0	26	0.46
11	0	27	0
12	0	28	0
13	0	29	0
14	0	30	0
15	0.05	31	trace
16	0		
		TOTAL FOR MONTH	1.25

* sampling date
** By the National Oceanic and Atmospheric Administration, unpublished memo.

TABLE A-3

PRECIPITATION DATA AS RECORDED** AT COHASSET, MA.

AUGUST, 1987

DATE	PRECIPITATION (inches)	DATE	PRECIPITATION (inches)
1	0	17*	0
2	0	18	0
3*	0.29	19	0
4	0.17	20	0
5	0	21	0
6	0	22	0
7	0	23	0.11
8	0.28	24	0
9	0.01	25	0
10*	1.62	26	0
11	0.02	27	0
12	0	28	0.34
13	0	29	0.73
14	0	30	0.19
15	0	31	0
16	0		
		TOTAL FOR MONTH	3.76

* sampling date
** By the National Oceanic and Atmospheric Administration, unpublished memo.

TABLE A-4

NORTH RIVER

SPECIES DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

JUNE 15, 1987

		NUMBER OF COLONIES					
Station	Total Tested	*Streptococci faecium*	*Streptococcus faecalis* var *liquefaciens*	*Streptococcus faecalis* var *zymogenes*	Tentative Group Q	Atypical Fecal Streptocccocci	Non-Fecal Streptococci
FH01	1	-	1	-	-	-	-
FH02	1	-	1	-	-	-	-
FH05	2	-	-	2	-	-	-
FH07	1	1	-	-	-	-	-
FH08	6	-	2	4	-	-	-
SD01	2	-	2	-	-	-	-
SD02	5	1	4	-	-	-	-
TOTALS	18	2	10	6	0	0	0
Percent	100	11.1	55.6	33.3	0	0	0

TABLE A-5

NORTH RIVER

BACTERIAL DATA

JUNE 15, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Coliform Bacteria MPN/100 ml	Fecal Streptococci Bacteria CFU/100 ml
FH01	80	130	10
FH02	60	20	10
FH03	160	--	<10
FH04	80	78	<10
FH05	50	78	20
FH06	30	--	10
FH07	200	130	20
FH08	190	--	100
FH09	10	--	<10
SD01	10	--	20
SD02	140	--	150
NR01	40	--	<10

TABLE A-6

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

JUNE 15, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
FH01	20.5	--	--
FH02	20.5	11.8	155.5
FH03	27	8.8	128.8
FH04	19.5	7.0	90.5
FH05	19	--	--
FH06	19.5	--	--
FH07	23	5.0	68.3
FH08	24.5	--	--
FH09	23	6.6	77.1
SD01	21	--	--
SD02	23	--	--
NR01	21	6.3	83.0

TABLE A-7

NORTH RIVER

CHEMICAL DATA (mg/l)

JUNE 15, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
FH01	15,500	1.2	0.07	*	0.10
FH02	14,500	1.3	0.07	*	0.08
FH03	14,000	6.4	0.39	*	2.1
FH04	15,000	1.2	0.06	*	0.13
FH05	15,500	1.6	0.03	*	0.10
FH06	14,500	1.5	0.05	*	0.10
FH07	13,500	5.8	0.13	*	0.20
FH08	200	1.9	0.22	*	0.12
FH09	100	1.3	0.16	*	0.14
SD01	108	0.76	0.06	1.3	0.02
SD02	78	1.9	0.50	2.8	0.71
NR01	13,400	1.7	0.04	*	0.06

* interference

TABLE A-8

NORTH RIVER

PHYSICAL DATA

JUNE 15, 1987

Station Number	pH (Standard Units)	Total Hardness (mg/l)	Turbidity (NTU)
FH01	7.7	2995	1.2
FH02	7.6	2900	1.2
FH03	7.1	1055	4.5
FH04	7.7	2860	0.9
FH05	7.8	3485	1.1
FH06	7.7	2990	1.0
FH07	7.0	2785	2.3
FH08	6.0	50	2.8
FH09	4.8	14	1.1
SD01	7.0	29	0.4
SD02	6.8	124	3.0
NR01	7.4	2735	0.9

TABLE A-9

NORTH RIVER

SPECIES DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

JUNE 22, 1987

NUMBER OF COLONIES

Station	Total Tested	Streptococci faecium	Streptococcus faecalis var liquefaciens	Streptococcus faecalis var zymogenes	Tentative Group Q	Atypical Fecal Streptoccocci	Non-Fecal Streptococci
NR02	1	--	1	--	--	--	--
NR03	2	--	--	2	--	--	--
NR05	3	1	2	--	1	--	--
NR06	3	1	1	1	--	--	--
NR07	3	1	--	2	--	--	--
NR08	6	4	2	--	--	--	--
SD03	7	4	1	1	--	1	--
CB01	1	--	1	--	--	--	--
DW01	5	4	1	--	--	--	--
SHB01	10	3	5	1	--	--	1
SB01	4	1	1	--	1	--	1
TOTALS	45	19	15	7	1	1	2

TABLE A-10

NORTH RIVER

BACTERIAL DATA

JUNE 22, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Streptococci Bacteria CFU/100 ml	Enterococci Bacteria CFU/100 ml
NR02	100	10	10
NR03	120	20	20
NR04	160	<10	<10
NR05	200	30	30
NR06	900	30	180
NR07	40	30	100
NR08	1000	70	180
SD03	3100	1500	--
CB01	2000	100	--
DW01	2700	500	--
SHB01	1700	100	320
SB01	840	40	80

TABLE A-11

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

JUNE 22, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
NR02	15	6.8	79.7
NR03	16	6.6	78.9
NR04	16	--	--
NR05	17	--	--
NR06	18	--	--
NR07	18	5.3	62.5
NR08	18	--	--
SD03	16	--	--
CB01	17	5.2	60.1
DW01	19	5.4	61.5
SHB01	18	5.1	56.9
SB01	17	4.9	56.6

TABLE A-12

NORTH RIVER

CHEMICAL DATA (mg/l)

JUNE 22, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
NR02	14,750	1.3	0.12	*	0.08
NR03	14,500	1.0	0.67	*	0.07
NR04	13,750	0.97	0.95	*	0.08
NR05	12,250	0.55	0.25	*	0.07
NR06	10,000	0.72	0.23	*	0.07
NR07	9,500	1.5	1.4	*	0.11
NR08	7,000	1.5	0.32	*	0.09
SD03	190	1.6	1.2	*	0.24
CB01	9,000	1.4	0.10	*	0.09
DW01	6,750	1.6	0.06	*	0.08
SHB01	3,750	1.4	0.15	*	0.11
SB01	10,000	1.5	0.63	*	0.09

* interference

TABLE A-13

NORTH RIVER

PHYSICAL DATA

JUNE 22, 1987

Station Number	pH (Standard Units)	Total Hardness (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)
NR02	7.4	8000	2.3	5.7
NR03	7.6	4650	3.5	7.7
NR04	7.4	4275	2.9	5.0
NR05	6.9	4425	3.1	6.0
NR06	7.0	3475	1.4	3.0
NR07	7.0	2895	2.4	1.3
NR08	6.8	2575	2.9	3.0
SD03	7.3	98	13	7.0
CB01	6.9	1895	1.7	7.0
DW01	7.0	1340	1.8	8.0
SHB01	6.7	2260	2.1	1.0
SB01	7.2	3755	1.3	0.0

TABLE A-14

NORTH RIVER

SOURCE DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

JUNE 29, 1987

		NUMBER OF COLONIES				
Station	Total Tested	Non-Fecal Streptococci	Tentative Group Q	Warm-blooded Animals	Insects	Vegetation
NR09	6	--	--	4	2	--
NR10	5	--	--	5	--	--
NR11	4	--	--	4	--	--
NR14	2	--	--	2	--	--
NR15	1	--	--	1	--	--
HP01	1	--	--	1	--	--
TOTALS	19	0	0	17	2	0
Percent	100	0	0	89.5	10.5	0

TABLE A-15

NORTH RIVER

BACTERIAL DATA

JUNE 29, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Streptococci Bacteria CFU/100 ml	Enterococci Bacteria CFU/100 ml
NR09	160	70	220
NR09	160	60	370
NR10	130	50	200
NR10	170	50	230
NR11	100	10	140
NR11	120	40	130
NR12	40	10	50
NR12	60	<10	50
NR13	30	<10	40
NR13	40	<10	60
NR14	40	<10	50
NR14	70	20	90
NR15	10	<10	<10
NR15	30	10	40
THB01	20	10	40
THB01	30	<10	60
HP01	20	20	30
HP01	80	<10	20

TABLE A-16

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

JUNE 29, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
NR09	21	7.1	79.7
NR10	21	--	--
NR11	21	6.6	74.1
NR12	22	--	--
NR13	22	6.7	76.8
NR14	21	6.9	77.5
NR15	22	7.7	88.3
THB01	25	9.1	110.4
HP01	23	11.8	137.8

TABLE A-17

NORTH RIVER

CHEMICAL DATA (mg/l)

JUNE 29, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
NR09	970	1.5	0.35	<0.1	0.25
NR10	270	1.3	<0.02	<0.1	0.10
NR11	170	0.96	<0.02	0.1	0.08
NR12	88	0.82	<0.02	0.3	0.08
NR13	64	0.50	0.02	0.3	0.09
NR14	54	0.79	0.02	0.3	0.08
NR15	48	1.4	0.04	0.8	0.15
THB01	60	1.2	0.04	0.4	0.10
HP01	100	1.4	0.02	0.4	0.07

TABLE A-18

NORTH RIVER

PHYSICAL DATA

JUNE 29, 1987

Station Number	pH (Standard Units)	Total Hardness (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)
NR09	6.8	280	4.5	150
NR10	6.7	83	2.9	5.0
NR11	6.6	58	2.6	6.3
NR12	6.7	41	2.7	3.5
NR13	6.7	31	2.5	9.7
NR14	6.8	33	2.3	0.0
NR15	7.5	30	3.2	1.0
THB01	6.6	31	9.0	2.0
HP01	7.1	41	3.2	0.0

TABLE A-19

NORTH RIVER

SOURCE DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

JULY 7, 1987

		NUMBER OF COLONIES				
Station	Total Tested	Non-Fecal Streptococci	Tentative Group Q	Warm-blooded Animals	Insects	Vegetation
FH03	2	--	--	--	--	2
FH08	3	--	--	--	--	3
SD01	6	1	--	--	--	5
SD02	8	--	--	2	--	6
TOTALS	19	1	0	2	0	16
Percent	100	5.3	0	10.5	0	84.2

TABLE A-20

NORTH RIVER

BACTERIAL DATA

JULY 7, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Coliform Bacteria MPN/100 ml	Fecal Streptococci Bacteria CFU/100 ml	Enterococci Bacteria CFU/100 ml
NR01	10	--	<5	<5
NR02	5	--	<5	<5
FH01	<5	45	<5	5
FH02	60	490	<20	20
FH03	840	--	40	280
FH04	15	45	<5	<5
FH05	20	45	<20	<20
FH06	20	--	<20	<20
FH07	40	20	<20	<20
FH08	160	--	60	120
FH09	<5	--	<5	<5
SD01	<5	--	30	70
SD02	<5	--	60	20

TABLE A-21

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

JULY 7, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
NR01	18	6.8	84.6
NR02	16	---	---
FH01	17	---	---
FH02	17.5	6.0	74.7
FH03	18	4.9	54.7
FH04	17	7.0	85.4
FH05	18	---	---
FH06	18.5	---	---
FH07	20	5.7	73.7
FH08	23	---	---
FH09	21.5	6.8	77.9
SD01	17.5	---	---

TABLE A-22

NORTH RIVER

CHEMICAL DATA (mg/l)

JULY 7, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
NR01	14,500	1.1	0.06	*	0.09
NR02	16,000	1.0	0.04	*	0.08
FH01	16,250	1.4	0.07	*	0.07
FH02	13,500	0.95	0.21	*	0.21
FH03	5,500	2.7	1.2	*	2.1
FH04	15,500	1.3	0.04	*	0.11
FH05	15,250	1.5	0.05	*	0.15
FH06	14,750	0.84	0.06	*	0.11
FH07	14,000	**	**	**	**
FH08	55	1.3	0.23	*	0.13
FH09	35	1.4	0.13	*	0.15
SD01	65	1.2	0.03	1.2	0.03
SD02	30	1.2	0.05	<0.1	0.33

* Interference
** Sample bottle was broken in the laboratory.

TABLE A-23

NORTH RIVER

PHYSICAL DATA

JULY 7, 1987

STATION NUMBER	pH (STANDARD UNITS)	TOTAL HARDNESS (mg/l)	TURBIDITY (NTU)	SUSPENDED SOLIDS (mg/l)
NR01	7.6	2,675	1.0	4.7
NR02	7.8	2,800	0.6	1.7
FH01	7.4	2,855	0.8	4.3
FH02	6.9	2,750	2.4	5.0
FH03	6.4	1,000	4.7	7.0
FH04	7.4	3,280	1.0	5.3
FH05	7.5	2,720	1.2	6.3
FH06	7.5	2,855	1.3	9.3
FH07	7.0	**	1.8	5.7
FH08	6.6	25	3.6	4.7
FH09	6.6	22	4.1	14
SD01	7.0	16	0.5	1.0
SD02	9.5	37	5.3	8.3

** Sample bottle was broken in the laboratory.

TABLE A-24

NORTH RIVER

SOURCE DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

JULY 20, 1987

Station	Total Tested	Non-Fecal Streptococci	Tentative Group Q	Warm-blooded Animals	Insects	Vegetation
		NUMBER OF COLONIES				
DW01	1	--	--	1	--	--
DW02	2	--	--	--	--	2
DW03	2	--	--	1	--	1
SHB01	1	--	--	1	--	--
SHB04	5	--	--	4	--	1
SB02	9	2	--	6	--	1
NR08	1	--	--	--	--	1
SD03	6	1	--	5	--	--
TOTALS	27	3	0	18	0	6
Percent	100	11.1	0	66.7	0	22.2

TABLE A-25

NORTH RIVER

BACTERIAL DATA

JULY 20, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Coliform Bacteria MPN/100 ml	Fecal Streptococci Bacteria CFU/100 ml	Enterococci Bacteria CFU/100 ml
DW01	180	130	20	<20
DW02	600	—	200	600
DW03	<5	—	10	5
SHB01	140	210	20	40
SHB02	100	<20	<20	80
SHB03	<5	—	<5	<5
SHB04	20	—	100	20
CB01	40	<20	<20	<20
CB02	10	—	<5	<5
SB01	5	20	<5	<5
SB02	1,280	—	400	1,780
NR01	20	<20	<20	<20
NR07	40	—	<20	<20
NR08	20	—	20	<20
SD03	900	—	600	200

TABLE A-26

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

JULY 20, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
DW01	23	7.3	89.9
DW02	20	--	--
DW03	16	--	--
SHB01	21.5	--	--
SHB02	18	--	--
SHB03	24	--	--
SHB04	21.5	--	--
CB01	21	5.9	73.7
CB02	22	--	--
SB01	20.5	5.7	71.2
SB02	17	--	--
NR01	18	6.7	83.4
NR07	22	6.3	80.2
NR08	22	--	--
SD03	21.5	--	--

TABLE A-27

NORTH RIVER

CHEMICAL DATA (mg/l)

JULY 20, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
DW01	6,250	1.0	0.62	<0.1	0.08
DW02	110	1.3	0.27	<0.1	0.18
DW03	30	0.73	0.05	0.5	0.13
SHB01	1,750	1.1	0.02	<0.1	0.09
SHB02	66	0.61	0.03	<0.1	0.06
SHB03	38	0.47	0.06	0.1	0.05
CB01	10,250	0.70	0.04	<0.1	0.09
CB02	23	0.64	0.05	<0.1	0.12
SB01	11,000	1.0	0.03	<0.1	0.08
SB02	39	0.57	<0.02	<0.1	0.10
NR01	15,880	0.93	0.08	<0.1	0.10
NR07	7,630	1.3	0.14	<0.1	0.11
NR08	7,500	1.2	0.12	<0.1	0.09
SD03	540	1.1	0.40	0.2	0.22

TABLE A-28

NORTH RIVER

PHYSICAL DATA

JULY 20, 1987

Station Number	pH (Standard Units)	Total Hardness (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)
DW01	7.4	1,300	2.6	10
DW02	6.7	43	37	52
DW03	6.8	21	0.6	7.3
SHB01	7.2	575	1.6	0.0
SHB02	7.0	22	1.2	0.0
SHB03	7.1	19	0.8	1.0
CB01	7.4	1,735	1.7	4.0
CB02	7.2	15	1.2	5.0
SB01	7.4	2,085	2.3	3.0
SB02	7.2	17	2.5	0.0
NR01	7.8	2,790	1.4	4.0
NR07	7.4	1,945	1.9	0.0
NR08	7.2	1,310	2.3	4.0
SD03	7.1	158	8.2	10

TABLE A-29

NORTH RIVER

SOURCE DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

AUGUST 3, 1987

NUMBER OF COLONIES

Station	Total Tested	Non-Fecal Streptococci	Tentative Group Q	Warm-blooded Animals	Insects	Vegetation
FH01	8	2	--	4	--	2
FH01	2	--	--	2	--	--
FH02	8	--	--	6	--	2
FH02	2	--	--	1	--	1
FH03	1	--	--	1	--	--
SM01	8	1	--	5	--	2
SM01	5	--	--	4	--	1
SM02	8	--	--	7	--	1
SM02	4	--	--	4	--	--
SM03	8	--	--	6	--	2
SM03	2	--	--	2	--	--
SM04	8	--	--	7	--	1
SM04	6	--	--	5	--	1
SD01	8	1	--	7	--	--
SD01	8	1	--	7	--	--
SD02	8	--	--	6	--	2
SD02	8	--	--	5	--	3
TOTALS	102	5	0	79	0	18
Percent	100	4.9	0	77.5	0	17.6

TABLE A-30

NORTH RIVER

BACTERIAL DATA

AUGUST 3, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Coliform Bacteria MPN/100 ml	Fecal Streptococci Bacteria CFU/100 ml	Enterococci* Bacteria CFU/100 ml
FH01	180	460	110	—
FH01	500	220	200	—
FH02	350	—	220	—
FH02	400	—	200	—
FH03	280	—	10	—
FH03	700	—	<100	—
FH09	100	—	<100	—
WI01	5	—	<5	—
WI01	<5	—	<5	—
WI02	10	—	<5	—
WI02	<5	—	<5	—
SM01	1,870	2800	560	—
SM01	1,100	5400	500	—
SM02	2,020	—	260	—
SM02	1,300	—	400	—

*Possibly contaminated media; data not reported

TABLE A-30 (CONTINUED)

AUGUST 3, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Coliform Bacteria MPN/100 ml	Fecal Streptococci Bacteria CFU/100 ml	Enterococci* Bacteria CFU/100 ml
NR00	20	18	<10	--
NR00	10	45	<10	--
SD01	3,000	3,500	3,300	--
SD01	4,700	3,500	6,600	--
SD02	<10	--	300	--
SD02	<10	--	30	--

* Possibly contaminated media, data not reported

TABLE A-31

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

AUGUST 3, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
FH01	19.0	8.1	97.3
FH02	20.0	--	--
FH03	21.5	--	--
FH09	22.0	--	--
WI01	19.5	6.6	85.3
WI02	19.0	--	--
SM01	21.5	--	--
SM02	21.5	--	--
SM03	21.5	--	--
SM04	22.0	5.7	76.5
NR00	20.0	7.0	90.5
SD01	21.0	--	--
SD02	22.0	--	--

TABLE A-32

NORTH RIVER

CHEMICAL DATA (mg/l)

AUGUST 3, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
FH01	10,000	2.1	0.45	<0.1	1.1
FH02	7,750	2.6	0.80	<0.1	1.8
FH03	1,000	4.1	0.70	<0.1	2.6
FH09	45	39	0.48	<0.1	8.8
WI01	15,750	1.3	0.10	<0.1	0.10
WI02	16,000	0.20	0.06	<0.1	0.12
SM01	14,500	1.4	0.04	<0.1	0.11
SM02	14,250	1.2	0.06	<0.1	0.11
SM03	13,500	2.8	0.72	<0.1	0.20
SM04	13,750	1.6	<0.02	<0.1	0.11
NR00	16,000	0.84	0.03	<0.1	0.12
SD01	25	1.5	0.21	0.1	0.16
SD02	70	0.96	0.14	<0.1	0.31

TABLE A-33

NORTH RIVER

PHYSICAL DATA

AUGUST 3, 1987

Station Number	pH (Standard Units)	Total Hardness (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)
FH01	7.5	1,560	7.0	45
FH02	7.4	1,140	7.3	21
FH03	7.7	340	5.8	29
FH09	5.3	7	120	4,940
WI01	7.8	246	2.3	11
WI02	7.9	2,460	1.7	17
SM01	7.6	4,150	3.3	8
SM02	7.6	2,260	3.7	29
SM03	7.6	2,050	4.2	30
SM04	7.5	2,420	2.8	10
NR00	7.7	2,190	1.8	3.5
SD01	6.8	11	18	16
SD02	9.7	43	92	190

TABLE A-34

NORTH RIVER

SOURCE DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

AUGUST 10, 1987

		NUMBER OF COLONIES				
Station	Total Tested	Non-Fecal Streptococci	Tentative Group Q	Warm-blooded Animals	Insects	Vegetation
NR09	10	--	--	8	--	2
NR10	10	1	--	5	--	4
NR11	7	1	--	6	--	--
NR12	10	--	--	3	--	7
NR13	10	--	--	4	--	6
NR14	10	--	--	6	--	4
NR15	10	1	--	3	--	6
CP01	8	1	--	3	--	4
HP01	8	--	--	5	--	3
TOTALS	83	4	0	43	0	36
Percent	100	4.8	0	51.8	0	43.4

TABLE A-35

NORTH RIVER

BACTERIAL DATA

AUGUST 10, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Streptococci CFU/100 ml	*Escherichia coli* Bacteria CFU/100 ml
NR09	160	130	160
NR10	240	140	250
NR11	510	70	200
NR12	740	130	550
NR13	460	200	650
NR14	350	160	180
NR15	620	680	760
CP01	200	140	290
HP01	550	180	660

TABLE A-36

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

AUGUST 10, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
NR09	21	7.2	90.0
NR10	21	--	--
NR11	21.5	6.7	85.3
NR12	22	--	--
NR13	22	6.9	83.3
NR14	22	6.8	77.9
NR15	21	8.6	101.8
CP01	22	6.6	75.6
HP01	22	6.1	73.6

TABLE A-37

NORTH RIVER

CHEMICAL DATA (mg/l)

AUGUST 10, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
NR09	11,250	0.98	<0.02	*	0.14
NR10	9,500	0.84	<0.02	*	0.15
NR11	8,500	1.1	<0.02	*	0.14
NR12	5,250	1.2	<0.02	*	0.17
NR13	3,250	1.8	<0.02	*	0.15
NR14	2,250	1.4	<0.02	*	0.17
NR15	2,500	0.74	<0.02	*	0.22
CP01	1,500	1.7	<0.02	*	0.15
HP01	3,000	0.95	<0.02	*	0.17

* Interference

TABLE A-38

NORTH RIVER

PHYSICAL DATA

AUGUST 10, 1987

Station Number	pH (Standard Units)	Total Hardness (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)
NR09	6.7	3,270	1.7	1.0
NR10	6.5	3,430	1.8	1.5
NR11	6.6	1,970	1.9	2.0
NR12	6.6	1,530	2.5	1.5
NR13	6.6	955	2.9	3.0
NR14	6.5	860	3.2	2.0
NR15	6.9	40	5.7	2.0
CP01	6.5	479	3.5	2.0
HP01	6.6	719	2.7	1.0

TABLE A-39

NORTH RIVER

SOURCE DIFFERENTIATION OF THE FECAL STREPTOCOCCI BACTERIA

AUGUST 17, 1987

NUMBER OF COLONIES

Station	Total Tested	Non-Fecal Streptococci	Tentative Group Q	Warm-blooded Animals	Insects	Vegetation
NR08	1	--	--	1	--	--
DW01	2	--	--	1	--	1
DW02	2	--	--	1	--	1
DW05	3	--	--	3	--	--
SB02	9	--	--	7	1	1
SB04	1	--	--	1	--	--
SHB01	2	--	--	2	--	--
SD03	2	--	--	2	--	--
TOTALS	22	0	0	18	1	3
Percent	100	0	0	81.8	4.6	13.6

TABLE A-40

NORTH RIVER

BACTERIAL DATA

AUGUST 17, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	Fecal Coliform Bacteria MPN/100 ml	Fecal Streptococci Bacteria CFU/100 ml	Enterococci Bacteria CFU/100 ml
NR01	60	68	<20	80
NR07	20	—	<20	60
DW01	420	700	40	80
DW02	1,100	—	200	2,000
DW04	160	—	<20	20
DW05	20	—	60	280
CB01	40	78	<20	20
SB01	40	110	<20	40
SB02	320	—	180	—
SB04	20	—	5	10
SHB01	60	78	40	<20
SD03	300	—	200	200
Riverside	200	—	<100	900

TABLE A-41

NORTH RIVER

TEMPERATURE (°C), DISSOLVED OXYGEN (mg/l), PERCENT SATURATION (%)

AUGUST 17, 1987

Station Number	Temperature	Dissolved Oxygen	Percent Saturation
NR01	22	6.2	83.2
NR07	25	6.6	88.7
NR08	25	--	--
DW01	25	6.7	85.5
CB01	24.5	5.5	73.9
SB01	24	4.5	59.4
SHB01	24.5	6.0	72.8

TABLE A-42

NORTH RIVER

CHEMICAL DATA (mg/l)

AUGUST 17, 1987

Station Number	Chloride	Total Kjeldahl-Nitrogen	Ammonia-Nitrogen	Nitrate-Nitrogen	Total Phosphorus
NR01	15,250	0.80	0.09	*	0.05
NR07	7,750	0.90	0.03	*	0.04
NR08	5,750	1.1	0.10	*	0.04
DW01	5,000	0.88	0.05	*	0.09
DW02	50	2.5	1.3	*	0.53
DW04	90	0.80	0.63	0.7	0.14
DW05	3,250	0.68	0.04	*	0.02
CB01	9,000	0.95	0.09	*	0.04
SB01	10,500	0.78	0.03	*	0.07
SB02	32	0.52	<0.02	*	0.06
SB04	10	1.5	0.02	*	0.20
SHB01	1,500	1.4	0.02	*	0.07
SD03	250	1.5	0.45	0.2	0.26
Riverside	50	1.1	0.55	0.7	0.30

* Interference

TABLE A-43

NORTH RIVER

PHYSICAL DATA

AUGUST 17, 1987

Station Number	pH (Standard Units)	Total Hardness (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)
NR01	7.6	2,445	0.8	1.0
NR07	6.9	1,670	1.3	3.0
NR08	6.5	1,300	1.6	3.0
DW01	6.6	1,200	1.8	3.0
DW02	6.7	25	27	46
DW04	3.3	41	3.2	6.0
DW05	6.4	599	1.0	0.0
CB01	7.0	1,735	1.3	3.0
SB01	6.9	1,950	2.1	3.0
SB02	7.4	17	1.7	0.0
SB04	6.7	19	0.8	13
SHB01	6.8	496	1.2	1.0
SD03	7.3	2,330	1.0	13
Riverside	7.4	40	17	3.0

TABLE A-44

NORTH RIVER

BACTERIAL DATA

DECEMBER 7, 1987

Station Number	Fecal Coliform Bacteria CFU/100 ml	*Escherichia coli* Bacteria CFU/100 ml
FH09	20	20
FH10	<5	<5
SD01	<5	<5
FH11	<5	<5
SB04	5	5
SB02	5	5